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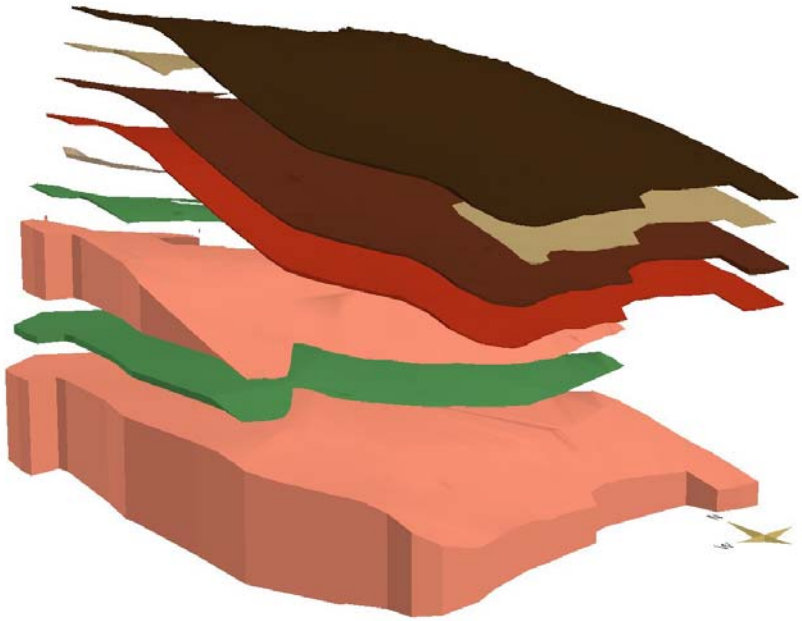
GSI3D – The software and methodology to build systematic near-surface 3-D geological models - Version 2.6

Geological Modelling Systems Team

Open Report OR/08/064



BRITISH GEOLOGICAL SURVEY

OPEN REPORT OR/08/064

GSI3D – The software and methodology to build systematic near-surface 3-D geological models - Version 2.6

S. J. Mathers & H. Kessler

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Key words

3 dimensional geological models, LithoFrame models, Quaternary, applied geology, shallow geosphere, geological survey, urban geosciences.

Front cover

Block diagram of Shelford in the Trent Valley near Nottingham showing modelling of soil horizons, superficial and bedrock geology.

Frontispiece

Block model down to the Chalk of NW London (upper) showing the addition of Lower Cretaceous units from a regional GoCad model (lower).

Bibliographical reference

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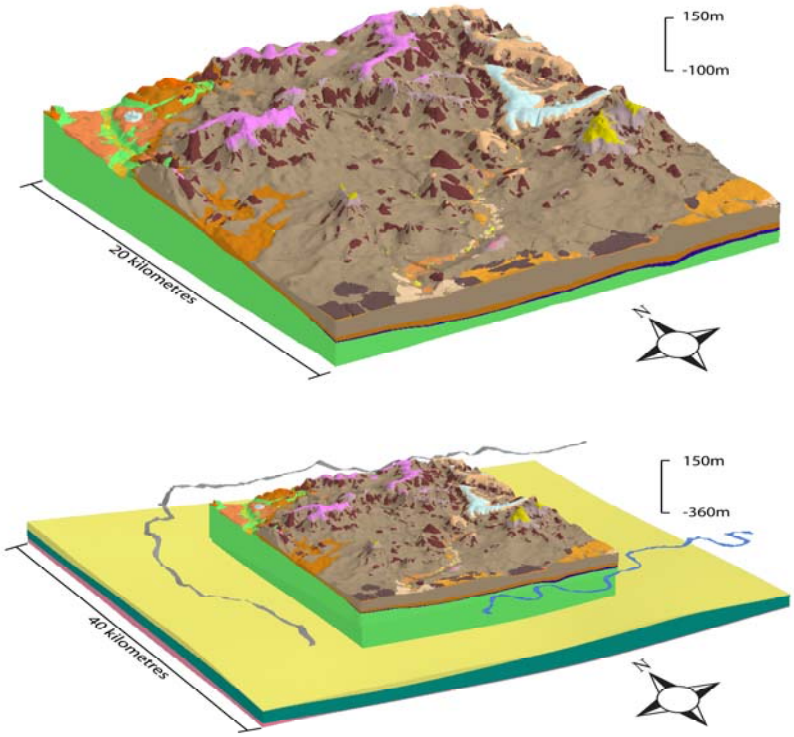

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Acknowledgements

This user-manual has been written by Steve Mathers and Holger Kessler at the British Geological Survey in collaboration with Dr Hans-Georg Sobisch (INSIGHT GmbH) the programmer and developer of the GSI3D (Geological Surveying and Investigation in 3-D) software. It is a guide for geologists in BGS, and elsewhere, to using the software and methodology to construct 3D geological models.

The GSI3D software was initially developed during the 1990s by Dr Sobisch for use in Quaternary sequences in northern Germany in collaboration with Drs Hinze and Mengeling at the NLfB (Niedersaechsisches Landesamt fuer Bodenforschung), which is the Soil and Geological Survey of Lower Saxony, based in Hanover. Over the past 7 years BGS has acted as a test bed for the accelerated development of the tool and methodology initially through the DGSM project and subsequently through take-up mainly by the Urban and Systematic Survey programmes.

Many people have contributed to the process of supporting and developing the software and methodology at the BGS. To-date over 125 BGS staff have been trained to use the software with over half of those actually going on to model within projects. Whilst initial work was carried out in the Science Budget programme an increasing amount of commissioned models have been built for commercial clients including local government and in particular the Environment Agency of England and Wales. The feedback and suggestions for further development of the software and methodology generated by the staff working on these projects and our customers are gratefully acknowledged. With the release of this Version 2.6 of GSI3D covered by this manual, the software now represents a complete and finalized solution for the construction of geological models in superficial and structurally simple stratified bedrock sequences. Especially thanks are due to, Gerry Wildman for contributing the section on GIS tools and Hans-Georg Sobisch for the explanations of new functionality during the compilation of this latest, third, edition of the GSI3D software manual.

Steve Mathers & Holger Kessler
BGS Keyworth
10 November 2008

1. Introduction

Quotes:

Nur einfache Lösungen sind gute Lösungen - Only simple solutions are good solutions (Hans-Georg Sobisch 2001)

'The familiarity which geologists and geophysicists have with this methodology [working with cross-sections] suggests it as a sensible, user-friendly approach to working with a truly three-dimensional modelling system.' (*Dabek, et al. 1989*)

1.1 Historical context

The Geological Surveying and Investigation in 3 Dimensions (GSI3D) software tool and methodology has been developed by Dr. Hans-Georg Sobisch (INSIGHT GmbH) over the last 15 years. Initially development was in collaboration with Drs.Carsten Hinze and Heinrich Mengeling of the NLfB (Niedersaechsisches Landesamt fuer Bodenforschung - Soil and Geological Survey of Lower Saxony) based in Hannover (Hinze, Sobisch and Voss, 1999; Sobisch 2000). From 2000-04 BGS acted as a test bed for the accelerated development of the tool and methodology initially through the DGSM project and take-up by the Urban, Integrated Geoscience Surveys and Coastal Geology programmes. In 2004 BGS bought a perpetual unrestricted license for the use of GSI3D v 1.5 and in 2005 upgraded to GSI3D Version 2. The current licensed Version 2.6 has been developed to include a workspace for project files.

1.2 Scope of GSI3D

The 3-D investigation and characterisation of the Earth's sub-surface is the prime objective of any geological survey. So far the **strategic** deliverables and products of such surveys have been 2-dimensional geological maps (polygons without height information) and in BGS best practice has been to present the distribution of geological units at the land surface and also at rockhead. These Bedrock and Superficial versions (formerly Solid and Drift) of maps only delineate the full extent of the uppermost unit in each of the two layers. 3-D buried geological data is only produced for major surfaces such as unconformities and/or readily recognised surfaces (e.g. base of superficial deposits, top of Chalk, base of Permian etc).

With advances in computing power and technology and the availability of increasingly precise and sophisticated Digital Terrain Models (DTM) it is now possible to envisage a new survey concept and eventually a totally new survey product: **the systematic 3-D geological model** (Kessler & Mathers 2004, Kessler, Mathers & Sobisch 2008, Mathers, 2008).

GSI3D is one of a suite of software tools and methodologies that enable the construction of such 3-D models. In order to achieve the objectives of a geological survey (national coverage and uniform high standards) the creation of this product must rest in the hands of the scientists on the ground. Only their specialized knowledge of the geological processes and evolution of the landscape can ensure the integrity of the systematic 3-D geological model.

The success of the GSI3D methodology and software, is based on the fact that it utilizes exactly the same data and methods that geologists have been using for two centuries in order to make geological maps:

1. Boreholes classified lithologically and interpreted stratigraphically
2. Geological outcrop data (linework and measurements)
3. Topographic maps and latterly Digital Terrain Models (DTMs)
4. Cross-sections
5. Contoured maps of buried surfaces
6. Geophysical data
7. Geochemical and geotechnical measurements
8. Hydrogeological data

The true difference to conventional surveying practice is the increased speed/efficiency at which all data can be visualized and analysed in relation to all other information enabling new insights into the geometries of the deposits that have not been possible before.

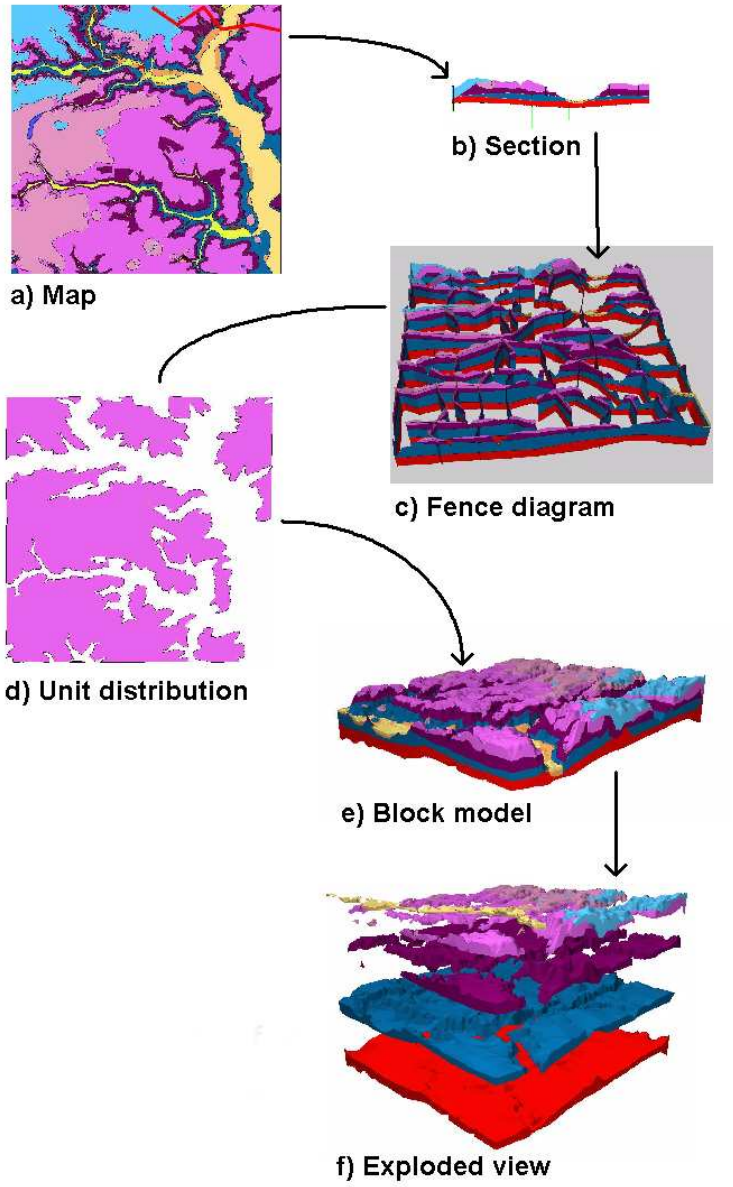
The use of intersecting user-defined cross-sections has been proved to be a solid and possibly the only tool to model the often complex geological situation in the shallow geosphere effectively (Mathers & Zalasiewicz, 1985, Dabek et al. 1989, Sobisch 2000, Kessler & Mathers 2004, Kessler, Mathers & Sobisch 2008, Mathers 2008).

As part of the 3-D modelling exercise the scientist is forced to continuously revise the integrity of the local stratigraphy. The entire 'stacking order' (4-D topology) of all deposits in a study area are captured in a Generalized Vertical Section (GVS). The ultimate aim is to establish a nationally valid GVS in hierarchical format ensuring the seamless 3-D model of the rock and superficial units (LithoFrame).

Once the geoscientist has:

a) completed the correlation of all units,
b) created all the boundaries of the geological units at surface and at depth and
c) defined the local stratigraphy

The 3-D model of the area is completed by computation. In this process the form of all the geological units in the model are calculated as triangulated, topologically sound **objects (a.k.a. shells, volumes)**.



In recent years INSIGHT GmbH has capitalised on the GSI3D technology and built the Sub-Surface Viewer as a means of delivering geological models to customers. This Viewer is not stand-alone software but the model is encrypted into it. The Sub-surface Viewer enables the client to visualise, slice, dice and query the block model that can be displayed according to multiple geological and applied parameters

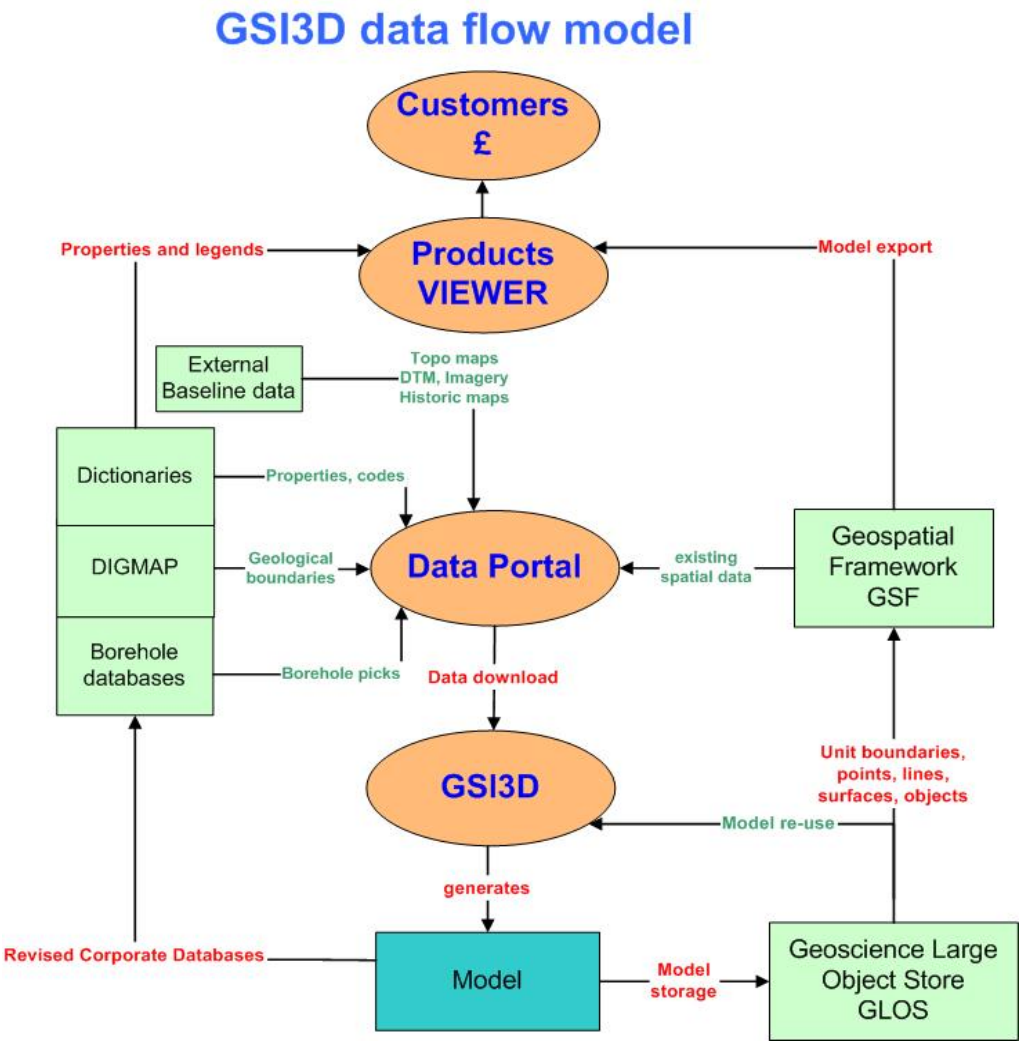
The GSI3D method aims to maintain a dynamic model of the near surface as part of the strategic surveying and continuous data revision process carried out by Geological Survey organisations. When new data or knowledge is obtained the geologist can review the new data (say boreholes), then, as needed, iterate the sections, envelopes or even introduce new units in the stratigraphy.

The ultimate aim is not to store fixed outputs (such as traditional maps, GIS layers or grids) but to maintain and continually upgrade an integrated geological model.

The GSI3D software and methodology has been developed for investigation of the shallow sub-surface. The actual depth to which modelling extends is variable depending on factors such as borehole depth, geological terrain and user requirements. The software cannot at present deal with heavily faulted and overturned strata but is being developed to encompass most scenarios encountered in bedrock environments (Mathers, Sobisch, Wood & Kessler, 2008).

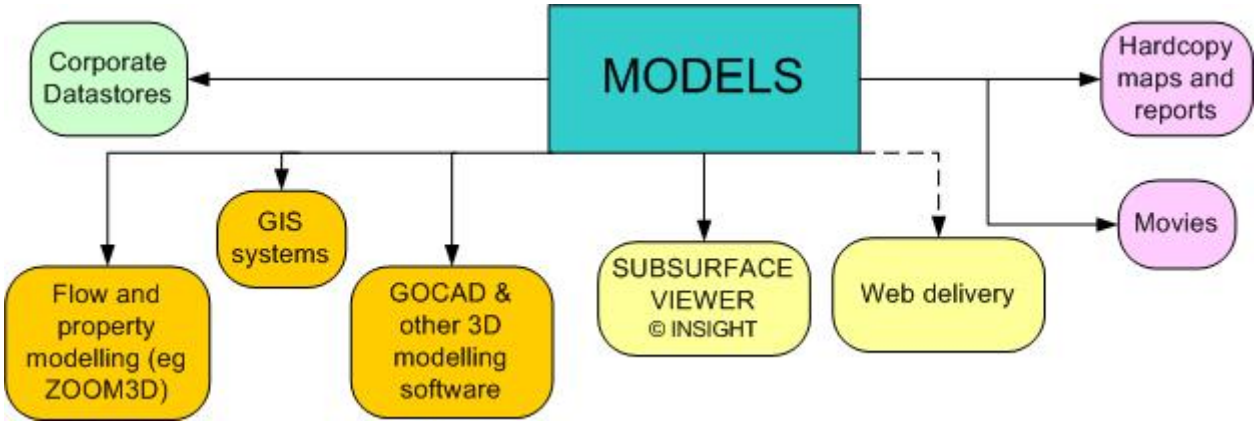
1.3. GSI3D data flow model

The figure below shows the data inter-relationships and flows to and from the BGS corporate databases and software and interaction with customers.
GSI3D uses BGS dictionaries (Lexicon; Rock Classification Scheme) and data formats and is therefore fully compatible with the main corporate databases.



1.4. Outputs from GSI3D projects

The following diagram shows what outputs can be generated from the GSI3D model.



The diagram shows general outputs and the tables below provide more specific details on data types and formats. Section 2 lists each file and data type exactly.

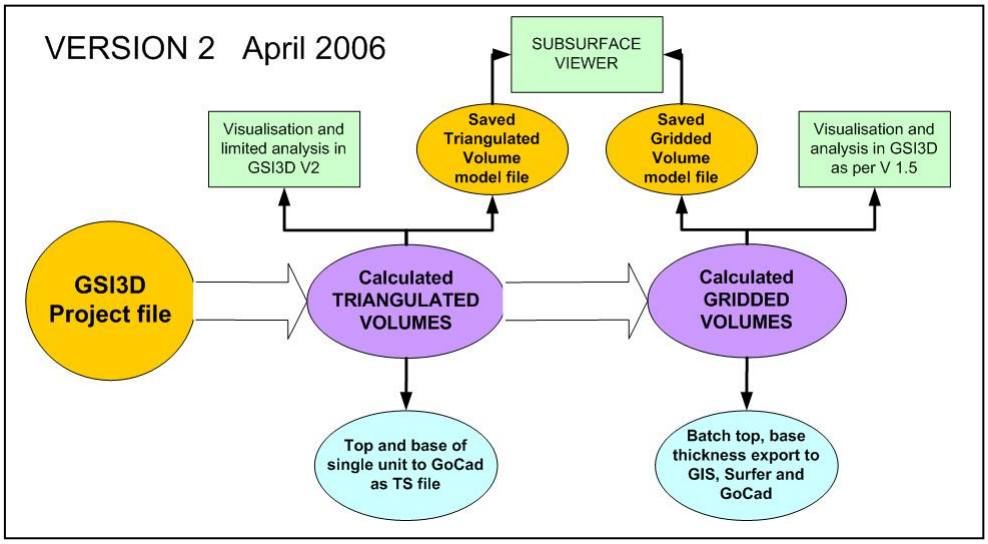
BGS corporate datastores	**Data type**
Geoscience Large Object Store (GLOS)	Folder containing all relevant project files
Geospatial Framework (GSF)	Attributed geological objects (tops, bases and walls) as stored in the model file
Borehole databases (SOBI and BOGE)	Tab separated ASCII files
DiGMapGB	Envelopes as ESRI shapes

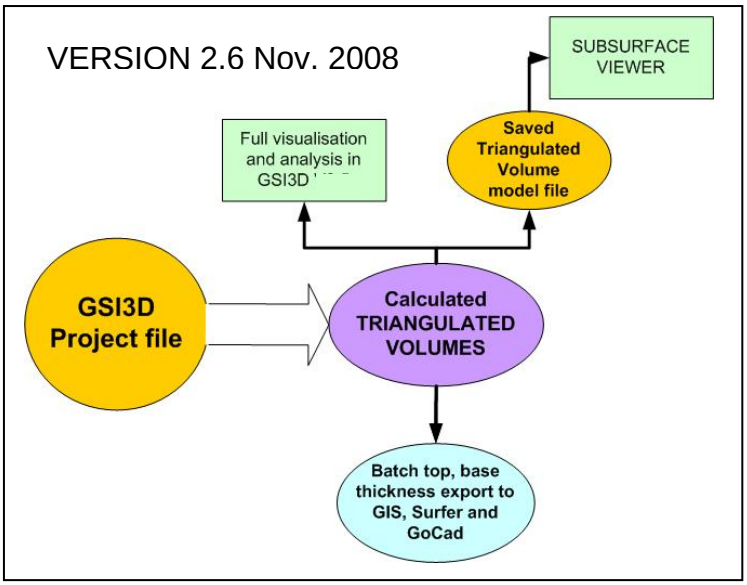
Other BGS software packages	**Data type and format**
SUBSURFACE VIEWER	Attributed Volume Models in gxml format
GoCad	GoCad TINS Scattered x,y,z in ASCII format
Earthvision	Standard ASCII grids Scattered x,y,z in ASCII format
Surfer	Surfer grids Scattered x,y,z in ASCII format
MapInfo	Standard ASCII grids and polygons as mid/mif files, geo-registered images
ESRI	Standard ASCII grids and ESRI shapes

Using the GSI3D_tools.mxd Arc project from Y:\GSI3D\GIS_tools, the user can batch convert all envelopes directly from a GXML file, retaining their attribution and topology (from the GVS file), and colour (from the legend file). The tool also allows the export of the section outline as an arc shape file. It is intended to also allow export of the sections as geological polygons.
A further option is to bulk convert existing polygons to envelopes in GXML format (see Section 5.2)

1.5 GSI3D recent developments

This manual describes the recently released Version 2.6 of the software, it differs fundamentally from the earlier Version 2 in that the calculation of the Model is now entirely TIN-based, so triangulated volumes are calculated by the number crunching function. In addition workspaces can be saved as project files. In the earlier versions grids were calculated and used extensively for analysis. The analytical function is now usually performed in the Sub-surface Viewer. The diagrams below illustrates the current flows within the software and relation to the Sub-surface Viewer contrasted with Version 2 from 2006


VERSION 2 April 2006
SUBSURFACE VIEWER
Visualisation and limited analysis in GSI3D V2
Saved Triangulated Volume model file
Saved Gridded Volume model file
Visualisation and analysis in GSI3D as per V 1.5
GSI3D Project file
Calculated TRIANGULATED VOLUMES
Calculated GRIDDED VOLUMES
Top and base of single unit to GoCad as TS file
Batch top, base thickness export to GIS, Surfer and GoCad


VERSION 2.6 Nov. 2008
SUBSURFACE VIEWER
Full visualisation and analysis in GSI3D
Saved Triangulated Volume model file
GSI3D Project file
Calculated TRIANGULATED VOLUMES
Batch top, base thickness export to GIS, Surfer and GoCad

2. Data files and formats

This section describes the basic data and their file formats used by GSI3D; detailed information about the actual loading process is given in Section 3.1.1.
It also includes a brief description about the extraction of some of the datasets via the BGS Data Portal, which directly accesses corporate datastores and converts data into a GSI3D format.

2.1. Supported file formats

In order to construct a new model GSI3D works with the following files (items in **bold** are essential for any modelling project):

Digital Terrain Models or other surface data (as ASCII grids)
Raster maps (as geo-registered JPEG images)
GIS data (as ESRI shapes)
Borehole data (SOBI and BoGe as ASCII text files)
Point measurements (as ASCII text files)
Sections and slices (as geo-registered JPEG images or grids)
Generalised Vertical Section - GVS (as ASCII text file)
Legend (as ASCII text file)

plus
Constructed sections and unit boundaries are progressively stored in a **project file *.gsipr (**as a XML/ASCII text file) as the model develops. So this file contains all the interpretive modelling work.

and
once a model has been completed and calculated, it is possible to store the DTM and all geological objects (top plus base) including their attribution as defined by the GVS and legend in a *.gxml **volume file**. This file can be reloaded into GSI3D for instant visualisation or also be encrypted into the Sub-surface Viewer for publication.

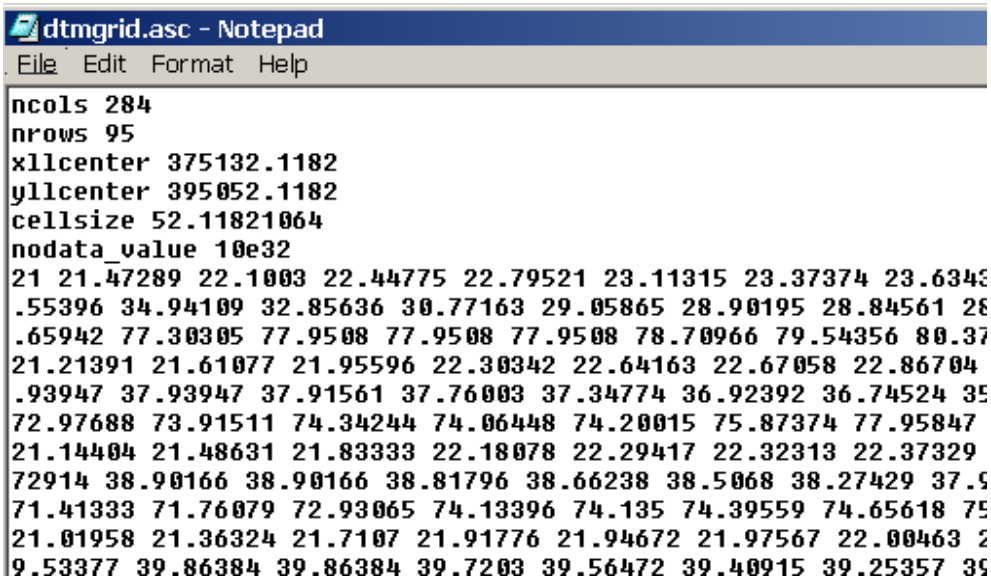
Sections 2.1.1 through to 2.1.10 below describe these various data files.

NOTE: All spatially held data should be working within a common Grid projection such as British National Grid, UTM or Gauss Krueger Netz.

NOTE: Because of the open data formats GSI3D can utilise any legacy data from projects and databases such as BLITH; LOIS; LOCUS; GEOHAZARD; GBASE etc. Data conversion can be achieved using standard tools such as Excel, and text editors (Notepad, Wordpad etc.)

2.1.1 Digital Terrain Models or other surface data

Existing surfaces and elevation models can be loaded into GSI3D as **standard ASCII grid files (*.asc)** in the following file format:



NOTE: A DTM (or another surface) is obligatory for the modelling process as it forms the 'cap' for all modelled units.

Any other required surfaces such as "Rockhead", watertables can be imported in this format and viewed in 2D or 3D. These surfaces can be selected to cap a GSI3D model with the resulting models truncated along surfaces other than the ground surface.

2.1.2 Raster maps

Rasters such as topographic maps, air photos, satellite images can be imported as geo-registered JPEGs (*.jpg with *.jpgw) the jpgw registration file can be created directly from BGS corporate tfw registration files by changing the file extension.
The size of these rasters should not exceed 10-15 MB as that will seriously impact on the performance of the software.

NOTE: The *.jpgw files used in GSI3D has its origin at its lower left corner

2.1.3 GIS data

Points, lines and polygons can be loaded into GSI3D as **standard ESRI shape file (*.shp)** and will be displayed in the map window. Only polygons can currently be used to create envelopes (Section 4.7). Colour information is not preserved with the GIS data and needs to be assigned via a separate legend file (Section 2.1.8).

The BGS digital map holdings - DiGMapGB (S:\DiGMapGB\Data) contain their information in separate layers these can be imported individually depending on need; but merged theme layers can be created from the four primary data layers listed below in any required combination

Artificial
Mass-movement
Superficial deposits
Bedrock geology

The standard DiGMapGB collection of themes does not include key geological features such as faults, mineral "veins" (including coal seams), fossil bands or structural measurements.
These data are available on request from Cartographic Services.

2.1.4 Borehole data

In a standard BGS modelling project using GSI3D digital borehole data is extracted into **tab separated ASCII files (*.bid and *.blg)** from the SOBI and BoGe databases using the DGSM data portal (Section 2.2).

The detail and methods of borehole coding depends on the project objectives, and it is recommended, where possible, to use corporate dictionaries for coding boreholes (see also Section 4.2).

The *.bid file is the borehole ID file, containing an ID, x, and y data to define each borehole location, and the start (collar) height relative to OD. The *.blg file is the borehole log file, with information **on the depth to base** of each of the identified units i.e. it is the downhole log file. This can be geological information from BoGe or any other downhole database organised in tab separated columns. The log must be 'complete' from the surface downwards and not intermittent; intervals of core loss are coded as absent data not left blank.

The borehole index file (*.bid) needs to be prepared with the following structure

Unique Borehole ID	Easting	Northing	Start Height
SE64SW23.	123456	123456	11.22

All boreholes MUST contain a number (-99999 if none available, not '.') in the start height column. If SOBI does not contain one, this can be added in a text editor. GSI3D displays borehole sticks according to their own start height, although the user has the option to 'hang' all sticks on the DTM if that is preferred. This option should be used with care, taking into account the relative confidence in the borehole datum's compared to the DTM. If confidence in the borehole datum is high, use the start height. If not, and the confidence in the DTM is relatively high, consider hanging the borehole sticks from the DTM).

The borehole log file (*.blg) needs to be prepared with the following structure

Unique Borehole ID	Depth to base of Unit from start height (in meters)	Lithostrat Code (Lexicon)	Lithology Code (RCS)	Other codes	More codes
SE64SW23.	1.23	ALV	CZ	ABC	DEF
SE64SW23.	4.56	LGFG	SV	ABC	DEF
SE64SW23.	7.89	LOFT	CSZV	ABC	DEF

NOTE: The Bid and Blg files must NOT contain any header information

NOTE: If the data is extensive as in big urban areas it is advisable to perform a manual retrieval by SQL. Alternatively any downhole data set can easily be compiled by hand in Excel.

NOTE: the blg file extension is unfortunately also used by Windows as a Performance Monitoring file. This means that double clicking on the blg file opens a windows application. This can be avoided by associating the blg file with Wordpad (right click on the file, Properties, Opens with, change to Notepad, tick "Always use the selected program to open files of this kind")

2.1.5 Parameter measurements

Numerical parameter data can be derived from geochemical analysis or geotechnical measurements, but can also include coloured-coded information on archaeological horizons.

In addition to the *.bid file giving locational x,y information GSI3D requires two tab separated ASCII text files in order to display numerical point data sets. Numerical down hole parameter are stored as a *.plg (parameter log) file and the legend with the respective threshold values are stored as a *.nvleg (numerical value legend) file. The location of these files is stored as a link within the *.gsipr project file.

The file with the numerical point values (*.plg) is structured in the same way as the ASCII text files for the lithological and stratigraphical downhole data (see a geochemical data set example below). In contrast to these logs, the *.plg file includes a first row, composed of the following columns for:

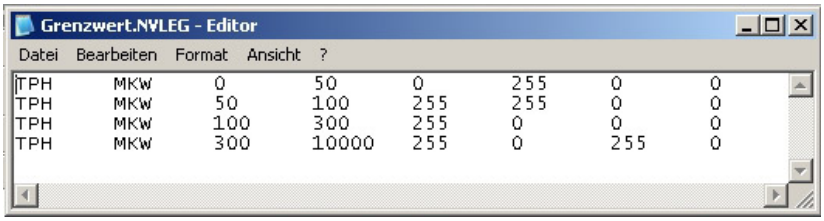
- the sample number or ID (meaning the ID of the borehole),
- the measured down-hole intervals (from z_1 to z_2, relating to the elevation of the surface, not the absolute elevation of the sample interval),
- all measured parameters.

Soil.PLG - Editor

Datei Bearbeiten Format Ansicht ?

Sample	from	to	Benzene	Toluene	Ethyl-benzene	p/m-Xylene		o-Xylene		Sum BTEX		Dichloro-m	
DR1	0	1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
DR1	1.2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
DR1	2	3	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.
DR1	3	4	3.59	2.74	3.23	8.30	0.57	18.43	0.37	0.00	11.67	0.00	10.40	1.
DR1	4	5	0.48	0.10	0.93	1.75	0.07	3.33	0.09	0.00	3.37	0.00	1.37	0.
DR2	0	1	0.00	0.00	0.00	0.00	0.00	0.00						
DR2	1	2	0.00	0.00	0.00	0.00	0.00	0.00						
DR2	2	3	0.20	0.32	0.14	1.16	0.02	1.85						
DR2	3	4	0.78	0.37	0.52	1.27	0.17	3.13						
DR2	4	4.8	1.51	2.26	1.21	3.05	1.16	9.22						
DR3	0	1	0.00	0.00	0.00	0.00	0.00	0.00						
DR3	1	2	0.00	0.00	0.00	0.00	0.00	0.00						
DR3	2	3												
DR3	3	4												
DR3	4	4.8	0.05	0.20	0.43	0.44	0.07	1.22						

The second required file is the legend *.nvleg file, giving the parameters for the upper and lower threshold values, according to given standards, and the respective colour-coding within the defined limits. The first column of the tabulator separated ASCII text file gives the name of the measured parameter and the second column an alias name of the parameter. Lines three and four define the upper and lower threshold values, respectively, according to the required standard, whereas lines five to eight give the chosen CYMK colour scheme; exemplified below in a TPH legend, with European standard threshold values in a simple green-yellow-red colour format.


Grenzwert.NVLEG - Editor
Datei Bearbeiten Format Ansicht ?
TPH MKW 0 50 0 255 0 0
TPH MKW 50 100 255 255 0 0
TPH MKW 100 300 255 0 0 0
TPH MKW 300 10000 255 0 255 0

NOTE: This separation of the *.plg and *.nvleg files allows a visualization of the measured parameters stored in the *.plg file, compared to various national or international standards, stored in respective *.nvleg files.

2.1.6 Sections and slices

Geo-registered sections and slices (horizontal sections) can be integrated for a common visualization with the stratigraphical/lithological dataset in the section window and/or with the cross-section network and the structural model in the 3D window. The location of these images and their registration details are stored in the *.gsipr project file, but currently still need to be loaded manually using the import function (see Section 3.1.1)

Sections can be visualized in the section and 3D windows. In order to display sections they have to be geo-registered, by defining the lower left and upper right coordinates in the x, y and z direction. This information is stored in a *.gxml registration file shown below.

Slices (horizontal sections) can be either be a picture or a grid files (*.gif, *.jpg, *.rst, *.asc or *.grd) and are geo-registered via a *.gxml file which has to be located in the same folder as the data file.

The following figure describes the*.gxml file structure for horizontal geophysical slice with absolute elevation

```
<HORIZONTALSLICE NAME="L3">
<TRANSFORMINFO XLL="668751.0" YLL="303246.0" XSPACING="0.256132"
YSPACING="0.256132" ROTATIONANGLE="0.0" FIXELEVATION="144.615" />
<HORIZONTALSLICEURL NAME="file://C:\Dokumente und Einstellungen\Alex\Eigene
```

The following figure describes the*.gxml file structure for horizontal geophysical slice with elevation relative to DTM

```
<HORIZONTALSLICE NAME="l1">
<TRANSFORMINFO XLL="668751.0" YLL="303246.0" XSPACING="0.256132"  YSPACING="0.256132"
ROTATIONANGLE="0.0" DELTAELEVATION="0.0"
ELEVATIONREFERENCE="file://D:\BGS\trainingskurs\Ungarn\Side-Logs\dtm.asc" />
<HORIZONTALSLICEURL
NAME="file://D:\BGS\trainingskurs\Ungarn\Side-Logs\Geophysik\Dip_Cut_Gif\L1.gif" />
</HORIZONTALSLICE>
```

NOTE: The project *.gsipr file only stores a link to the geophysical picture or grid, referring to the location of the respective picture or grid while geocoding, see picture below. Changing the location of the picture or grid into another folder will result in loss of

the data for the picture or grid. But if these files are in the same directory as the *.gsipr project file the system automatically checks this directory and chooses the indicated picture. This enables the transfer of the complete folder (*.gsipr and slices) into a differing directory environment.

2.1.7 Generalised Vertical Section – GVS

The GVS file is a **tab separated ASCII text file; (*.gvs)** and forms the backbone of the GSI3D project. It is produced by the modeller, evolving throughout the project and finally contains all units in their correct and unique super-positional order as the order itself defines the 'model stack' that is calculated to make the 3-D geological model. This can be a lithostratigraphical order or chronology of artificial (man-made) deposits.

The table below shows the essential elements of the GVS file:

Name	id	Stratigraphy	Lithology	Genesis	Free text
Alv	10	ALV	CZ	Fluv	Overbank...
Lgfg	20	LGFG	SV	glac_fluv	Sheet sands...
Loft	30	LOFT	CSZV	Glac	Lodgement till…
Sand_lens_t	-150	SAND_L	S	glac_fluv	Intra till lense (top)
Sand_lens_b	150	SAND_L	S	glac_fluv	Intra till lense (base)

Name — the model code provides the link to the correlation lines and must be unique. The order from top to bottom MUST be the stratigraphic order of the entire model area. (Except for lenses, see Section 2.4)

id — The ID column is used internally to differentiate between "normal" layers/units and lenses. In the future it may also be used to link databases directly to the GVS. The LINK_ID must be an integer number between -65000 and +65000 with no decimals

Stratigraphy… — This field, and any subsequent fields, are used to provide the link to the legend file. The legend field entries are caps sensitive and must match exactly the entry in the legend file. There can be multiple fields in order to colour up the model by other parameters.

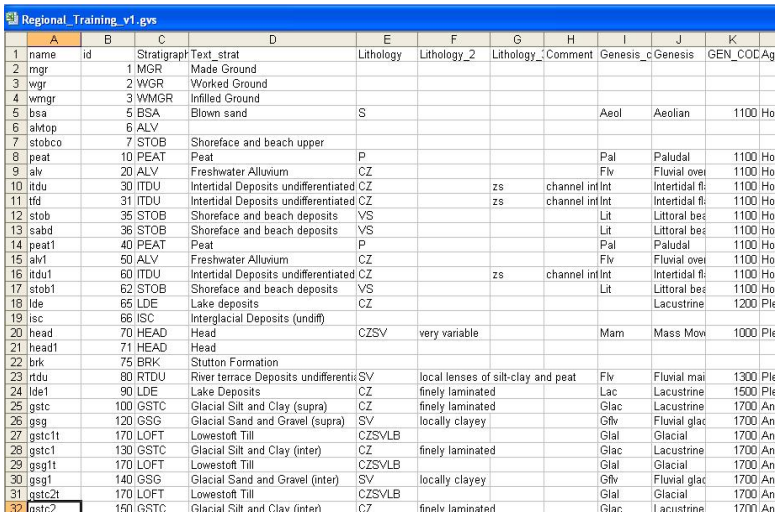
TIP: It is recommended to generate the GVS in WordPad or EXCEL

NOTE: The GVS file can, but does not have to contain any headers.
However, if the model is to be published using the *Sub-surface Viewer,* column header names are necessary, as they will be displayed in the property pick list. It is therefore important to give concise and meaningful names that can be understood by your envisaged client.

NOTE: The gvs file must not contain any special characters such as ' "& $

NOTE: All GSI3D files (but in particular the GVS file) must NOT contain an empty row at the bottom of the data file.

NOTE: The line entry at the top for the dtm cap used in earlier Versions is no longer needed.



Regional_Training_v1.gvs

	A	B	C	D	E	F	G	H	I	J	K	
1	name	id	Stratigraph	Text_strat	Lithology	Lithology_2	Lithology_	Comment	Genesis_c	Genesis	GEN_COD	Ag
2	mgr	1	MGR	Made Ground								
3	wgr	2	WGR	Worked Ground								
4	wmgr	3	WMGR	Infilled Ground								
5	bsa	5	BSA	Blown sand	S				Aeol	Aeolian	1100	Ho
6	alvtop	6	ALV									
7	stobco	7	STOB	Shoreface and beach upper								
8	peat	10	PEAT	Peat	P				Pal	Paludal	1100	Ho
9	alv	20	ALV	Freshwater Alluvium	CZ				Flv	Fluvial over	1100	Ho
10	itdu	30	ITDU	Intertidal Deposits undifferentiated	CZ		zs	channel int	Int	Intertidal fl	1100	Ho
11	tfd	31	ITDU	Intertidal Deposits undifferentiated	CZ		zs	channel int	Int	Intertidal fl	1100	Ho
12	stob	35	STOB	Shoreface and beach deposits	VS				Lit	Littoral bea	1100	Ho
13	sabd	36	STOB	Shoreface and beach deposits	VS				Lit	Littoral bea	1100	Ho
14	peat1	40	PEAT	Peat	P				Pal	Paludal	1100	Ho
15	alv1	50	ALV	Freshwater Alluvium	CZ				Flv	Fluvial over	1100	Ho
16	itdu1	60	ITDU	Intertidal Deposits undifferentiated	CZ		zs	channel int	Int	Intertidal fl	1100	Ho
17	stob1	62	STOB	Shoreface and beach deposits	VS				Lit	Littoral bea	1100	Ho
18	lde	65	LDE	Lake deposits	CZ					Lacustrine	1200	Pl
19	isc	66	ISC	Interglacial Deposits (undiff)								
20	head	70	HEAD	Head	CZSV	very variable			Mam	Mass Mov	1000	Pl
21	head1	71	HEAD	Head								
22	brk	75	BRK	Stutton Formation								
23	rtdu	80	RTDU	River terrace Deposits undifferentia	SV	local lenses of silt-clay and peat			Flv	Fluvial mai	1300	Pl
24	lde1	90	LDE	Lake Deposits	CZ	finely laminated			Lac	Lacustrine	1500	Pl
25	gstc	100	GSTC	Glacial Silt and Clay (supra)	CZ	finely laminated			Glac	Lacustrine	1700	An
26	gsg	120	GSG	Glacial Sand and Gravel (supra)	SV	locally clayey			Gflv	Fluvial glac	1700	An
27	gstc1t	170	LOFT	Lowestoft Till	CZSVLB				Glal	Glacial	1700	An
28	gstc1	130	GSTC	Glacial Silt and Clay (inter)	CZ	finely laminated			Glac	Lacustrine	1700	An
29	gsg1t	170	LOFT	Lowestoft Till	CZSVLB				Glal	Glacial	1700	An
30	gsg1	140	GSG	Glacial Sand and Gravel (inter)	SV	locally clayey			Gflv	Fluvial glac	1700	An
31	gstc2t	170	LOFT	Lowestoft Till	CZSVLB				Glal	Glacial	1700	An
32	gstc2	150	GSTC	Glacial Silt and Clay (inter)	CZ	finely laminated			Glac	Lacustrine	1700	An

Example of an extended GVS

2.1.8 Legend - GLEG

The legend file is used to assign colours and textures to the map polygons, borehole sticks, sections, and envelopes and is created as an **ascii tab separated text file; (*.gleg)**.
The file format is outlined below:

LEG_ID	Description	Red	Green	Blue	Transparency	Texture link
ALV	Sandy, clayey …	55	66	77	255	TEXTURES/gravel.jpg

LEG_ID	This column contains the codes corresponding to the entries in the GVS files (Stratigraphy, Lithology, Genesis, etc.) and the codes used in borehole log descriptions
Description	Free text description of the unit
Red	Red value (0-255)
Green	Green value (0-255)
Blue	Blue value (0-255)
Transparency	Pre-set transparency (0-255) (0 = transparent; 255 = full colour)
Texture link	This field contains the path to the Folder containing the texture JPGs

At the moment ‘standard textures’ have been created for the new Superficial Deposits Description Scheme (Kessler et al. 2004b) and are stored in the GSI3D program folder (Y drive) under TEXTURES. Any other customised textures must be stored in a common place and the Texture link must be changed accordingly (e.g. E/my_own_textures/my_gravel.jpg).

TIP: It is important to realize that RGB values for screen display need to be darker than those for printing.

NOTE: The legend file must NOT contain any header information. The Legend file works for all codes in GSI3D at the same time and clashes between matching codes in the Rock Classification Scheme and the LEXICON can occur.

2.1.9 The Project file - *.GSIPR

On saving the project, all sections and envelopes are written to the project *.gsipr file. This **ASCII text file (*.gsipr),** written in mark-up language, contains the sections (alignment and correlations) and envelope data (x,y polygons) of the model together with triangulated surfaces (e.g. dtms and other geological surfaces) as well as links to the following datasets, grids as *.asc , the *.gvs file, *.gleg file, *.bid and *.blg files, raster maps, including topo maps, and their registration.

Example Project File text

```
<?xml version="1.0" encoding="iso-8859-1"?>
<GSI3DPROJECT>
<GSI3D VERSION="2.6 demo   October 2008" />
<GVS URL="file://W:\SSM\3DSoil\Data\Shelford_data\3D_Model\SHELFORD_2.gvs" />
<LEGEND
URL="file://W:\SSM\3DSoil\Data\Shelford_data\3D_Model\3dsoil_SHELFORD_1.gleg"
/>
<BLG_FILE
URL="file://W:\SSM\3DSoil\Data\Shelford_data\3D_Model\3dsoil_SHELFORD.BLG" />
<DTM NAME="dtm" />
<MINIMUM_POINT_DISTANCE VALUE="1.0" />
<MAXIMUM_LENSE_BOUNDARY_DISTANCE VALUE="1.0" />
<MINIMUM_MODEL_DEPTH VALUE="-1000.0" />
<GRIDVIEWOBJECT NAME="tm24_50m_nextmap"
URL="file://E:\GSI3D\Training\Exercise data\TM24 data\TM24_50m_NEXTMAP.asc"
>
<GRIDLAYOUT  COLOR1="-16777216" COLOR2="-65536" COLOR3="-256" TYPE="1"
CLASSINTERVAL="1.0" SHADING="0.0" TRANSPARENCY2D="0.0" TRANSPARENCY3D="0.0"
/>
</GRIDVIEWOBJECT>
<SELECTED_ATTRIBUTE NAME="horizon" />
<DRILLLOGMAP NAME="3dsoil_shelford.bid">
<BOHRKOORDINATEN>
Shelford_Borehole_1     467468.0    342548.0    18.3
<IMAGEMAP NAME="shelford_site_map_50k"
URL="file://W:\SSM\3DSoil\Data\Shelford_data\3D_Model\Shelford_site_map_50K.j
pg" >
<WORLDINFO  X="465248.9" Y="344338.62" XS="2.1401093" YS="2.140269" B="2044"
H="1748" />
</IMAGEMAP>
<TINOBJECT NAME="dtm">
<SCHICHTPOLYGON>
<POLYGON>
37
467983.06   341588.38
467800.03   341804.72
467504.62   341742.3
467284.16   342000.25
467230.06   342062.66
<PROFILVIEWOBJECT NAME="ThamesG_NS_1">
<BOHRKOORDINATEN>
TQ57NE128.  557410      178040      2
```

```
TQ57NE454.  557500      177806      10.69
TQ57NE453.  557506      177788      5.41
TQ57NE452.  557518      177741      4.7
</BOHRKOORDINATEN>
"<LINE   NAME="rtdu">"
44
1125.3837   -8.93151
1130.5491   -11.304261
1137.4539   -12.983281
1936.5609   -14.045156
</LINE>
</PROFILVIEWOBJECT>
<SCHICHTOBJECT NAME="water">
<SCHICHTPOLYGON>
<POLYGON>
101
558374.3    175890.61
558245.75   175903.8
558813.75   176482.75
</POLYGON>
</SCHICHTPOLYGON>
</GSI3DPROJECT>
```

2.1.10 GSI3D Volume file *.gxml

After modelling all objects can be exported into a single *.gxml file containing all geological objects (top plus base) including their attribution as defined by the GVS and legend.

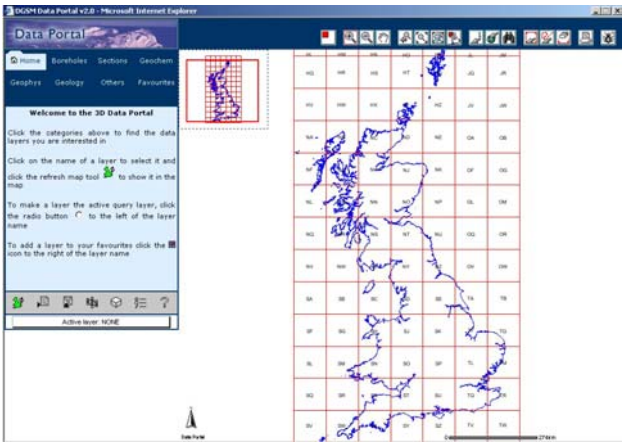
Example Volume File text

```
<GSI3DMODEL>
<ATTRIBUTENAME NAME="Geological_Description" />
<VOLUME  NAME="mgr" COLOR="-9548749" Geological_Description="made and worked
ground and topsoil" Geological_DescriptionCOLOR="-9548749" LENS="false">
<BASE>
<TIN>
<POINTS>
260007.7028 663709.7718 0
260007.7074 663708.7166 -0.187942802
260007.7466 663699.7329 -0.877495267
....
</POINTS>
<INDEXLIST>
0     18    1
18    95    2
18    2     1
....
</INDEXLIST>
</TIN>
</BASE>
<TOP>
<TIN>
<POINTS>
260007.7028 663709.7718 0
260007.7074 663708.7166 0
260007.7455 663700      0
....
</POINTS>
<INDEXLIST>
```

```
474    452    444
492    491    476
95     3      2
....
</INDEXLIST>
</TIN>
</TOP>
<GSI3DMODEL>
```

TIP: After changing the file extension to *.xml, any gxml file can be opened in Microsoft Internet Explorer in order to check the validity of the document – e.g. are any closing tags missing.

2.2 The BGS Data Portal



Using the BGS data portal (above) on the intranet the user can extract data from the BGS datastores into GSI3D ready to use format. The data portal has an in-built help facility shown by a question mark icon at bottom right of the menu window. The user has the choice of selecting data via 1:10K sheets or multiples thereof or any rectangular area using the map marquee. In its current release the portal serves:

- NEXTMAP DTM and rockhead elevation model with the ability to subsample
- SOBI with the ability to assign a missing start height from NEXTMAP
- BoGe with the ability to select by Interpreter and Content Code, as well as Stratigraphy
- Raster topo maps

In future releases the Portal will serve DiGMap and auto-compile GVS and Legend files from the codes and colours contained in the extracted data.

2.3 File structure and labelling

All working GSI3D projects should be stored on the Small Area Network (SAN) in BGS Keyworth currently mapped as the W drive.

When working in a strategic survey project it is recommended to create a folder for each 25K or 10K sheet with the name of the sheet (e.g. TM14, SJ79NE) when working in a special project this folder should have a short project identification code (e.g. MAN for the Manchester Urban project). This folder contains all GSI3D files described above at one level and an EXPORT folder containing 'frozen' grid and Volume exports from GSI3D.
Because the GVS and Legend file are usually relevant for multiple sheets or projects and can therefore be stored directly in the top folder, labelled sensibly like (MAN.gleg or SouthEastAnglia.gvs). This convention can be taken to all levels of the project including the names of the cross-sections (e.g. MAN_sec_NS1 or TM14_WE2).

\\kwnts9\programmes\LR\IGSS\SouthernEastAnglia\Ipswich modelling\TM24

Name	Size	Type	Modified
EXPORT		File Folder	31/07/2003 08:55
South_East_Anglia.gvs	7 KB	GVS File	06/02/2003 09:26
tm24.gleg	7 KB	GLEG File	31/07/2003 08:45
tm24_10k_comb_drift.avl	6 KB	AVL File	09/12/2002 16:07
tm24_10k_comb_Drift.dbf	382 KB	DBF File	09/12/2002 15:46
tm24_10k_comb_Drift.shp	734 KB	SHP File	09/12/2002 15:46
tm24_10k_comb_Drift.shx	2 KB	SHX File	09/12/2002 15:46
tm24_10k_solid.avl	3 KB	AVL File	09/12/2002 16:04
tm24_10k_Solid.dbf	48 KB	DBF File	09/12/2002 15:46
tm24_10k_Solid.shp	204 KB	SHP File	09/12/2002 15:46
tm24_10k_Solid.shx	1 KB	SHX File	09/12/2002 15:46
TM24_BOGEv2.blg	40 KB	BLG File	03/12/2002 16:02
tm24_CEH_dtm.asc	4,555 KB	ASC File	17/12/2002 19:02
TM24_export_tins.gxml	1,258 KB	GXML File	20/01/2003 16:18
TM24_project.gxml	718 KB	GXML File	14/01/2003 13:24
TM24_SOBIv2.bid	22 KB	BID File	03/12/2002 16:12
TM24_topo.jpg	1,411 KB	JPEG Image	31/07/2003 09:11
TM24_topo.jpgw	1 KB	JPGW File	31/07/2003 09:06

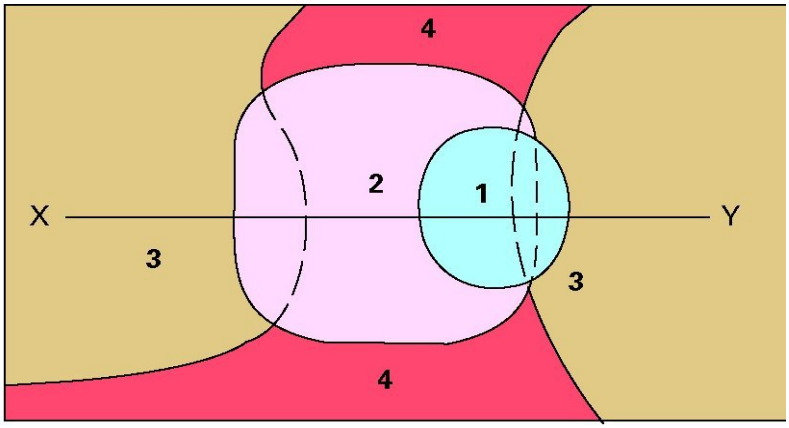
File Structure showing all the various types of required data files

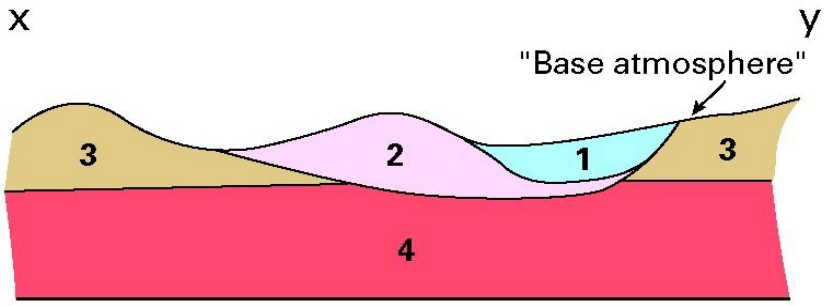
2.4 GSI3D basic principles

It is important to realise that, when working within GSI3D it is the **base of geological units** rather than the top that is defined and attributed in sections. GSI3D also requires the modeller to define the combined surface and concealed extent of each geological unit within the survey area. This distribution is termed the unit **envelope** and may be composed of a single or multiple **polygons**. The envelope is a presence/absence map of the geological unit.

The GVS file controls the order in which the geological unit can occur at any point and rejects any relationships drawn in sections or block models that do not correspond to this pre-determined order. When stacking the model the calculation works from the surface downwards first computing the top unit that lies between the DTM and its base within the area of its distribution (envelope). The next unit in the sequence is then computed within its envelope its top may be a combination of the DTM where it crops out and the base of the overlying unit where it is concealed.

The following plan and section views show a likely arrangement of four units in a stratigraphical sequence 4-1 from oldest to youngest.





Unit 1 has its base and its distribution envelope defined by its' surface outcrop, the DTM forms its top (i.e. base of atmosphere).

Unit 2 has its base and envelope defined by the limit of its' surface outcrop and its' subcrop beneath Unit 1, the top of this unit is a combination of part of the base of unit 1 where it rests on unit 2 and the DTM where it crops out.

Unit 3 has its base and envelope comprising two polygons bounded by the limits of its subcrop; whilst its upper surface corresponds to parts of the bases of units 1 and 2 and also segments of the DTM where it crops out.

Unit 4 forms the base of the stack and its base is not encountered but it is entirely concealed and continuous as the unit is present throughout the area. Therefore the envelope equals the project area. The top of this unit comprises elements of the bases of Units 2 and 3.

So the base of any unit is considered to be a single surface whilst the top (which is not defined) is composed of elements of other unit bases and sometimes the DTM if the given unit crops out.

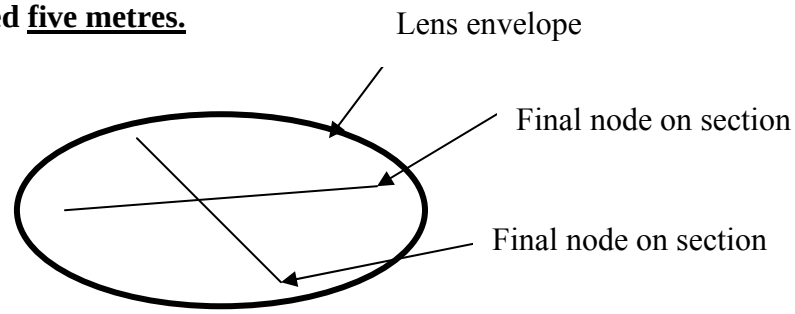
Lenses

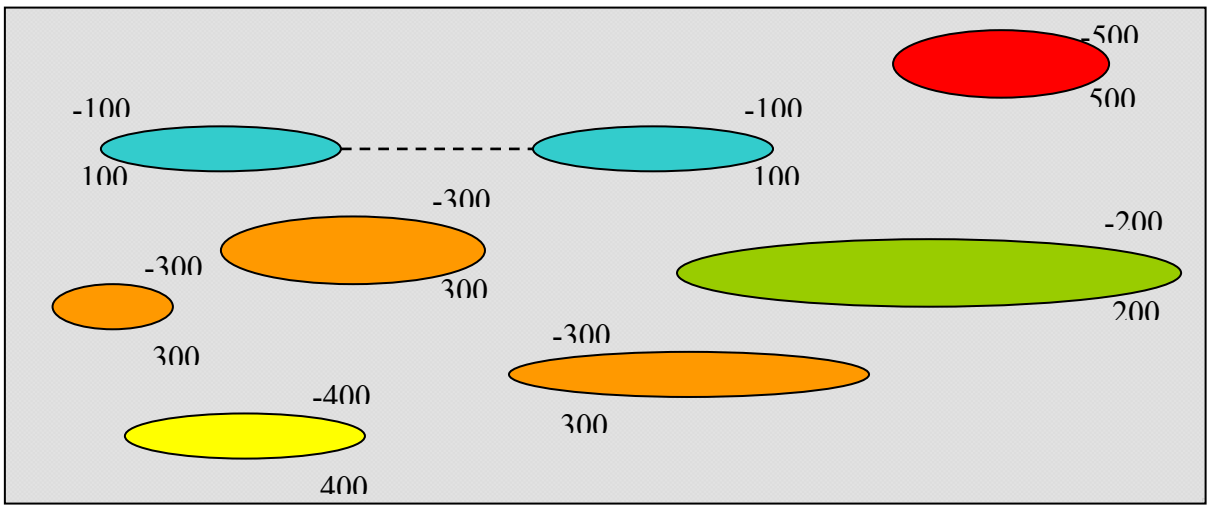
In the case of lenses within a parent body (grey) there are two cases to consider. Firstly the lenses may be co-eval (blue pair) meaning they are one stratigraphic unit that is discontinuous. In this case they are numbered the same. It is imperative that no two of these lenses will occur on top of each other.

Secondly lenses may occur that relate to different temporal events even though they have a similar lithology, geometry and parent body but the modeller has decided to still group them into one unit as described above (orange group)
Where a similar such lens vertically overlaps another of the group it must however be assigned a separate code (green lens over orange group)
If desired each lens can be treated as an individual, hence not implying any age relationship (red and yellow lenses)

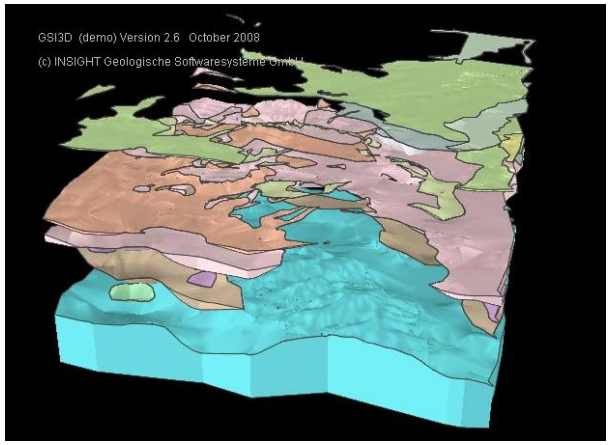
As lenses are treated as intrusions, they sit outside the GVS sequence. They should be listed at the bottom of the GVS (see Section 2.1.7) where in the ID column the top of the lens receives the negative numerical assignation as its corresponding base.
As intrusive bodies can therefore cross-cut the stratigraphic boundaries in the model.

NOTE: Because the elevation of the entire lense envelope is calculated from the final nodes on the correlation lines the separation between the final node and the envelope boundary must not exceed <u>five metres.</u>

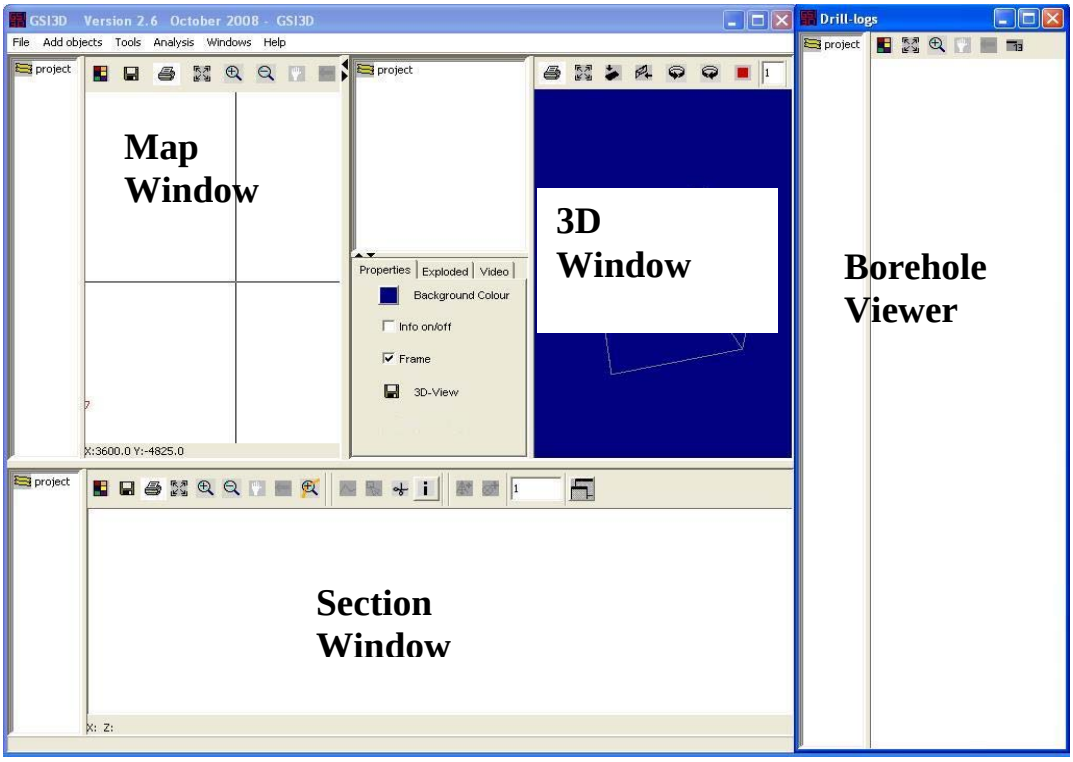




3. The GSI3D Interface



After starting the GSI3D software from the desktop shortcut icon (above) the MS_DOS window GSI3D title page and license details are displayed briefly (splash screen also above) before loading the main screen (below).



3.1 The Main Screen

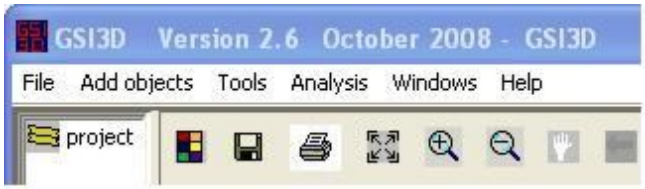
On loading GSI3D the basic screen is composed of three individual windows, the map window top left, the 3D window top right and the section window below. The Borehole viewer is loaded separately from the tools pull down menu (see Section 3.1.1.3). Arrows on the margins of the top windows allow each to be maximized or minimized, whilst clicking on the edges allow dragging

of the windows to any preferred size depending on the type of work being undertaken. Similarly the left hand Table of Contents (TOC) margin present within each window can also be enlarged or reduced in width within its own window. Most items in the software can be "right clicked" to get options, such as properties or print.

In the early stages of building the GSI3D model of any area the 3D window is generally switched off (see Section 3.4.1) to allow interactive working between the map window displaying themes such as geological lines, boreholes, lines of section and the section window containing all the sections already constructed.

Using the split window function (see Section 3.1.1.3) all windows can be arranged individually, switched off individually and docked together again.

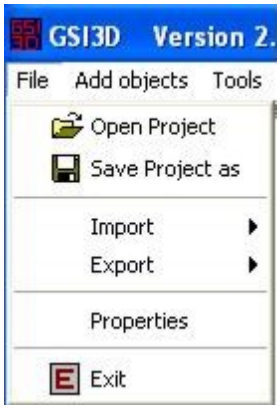
3.1.1 The pull down menus



The task bar of the main GSI3D window contains six pull down menu options (above):

3.1.1.1 File

contains the following options:



Open Project

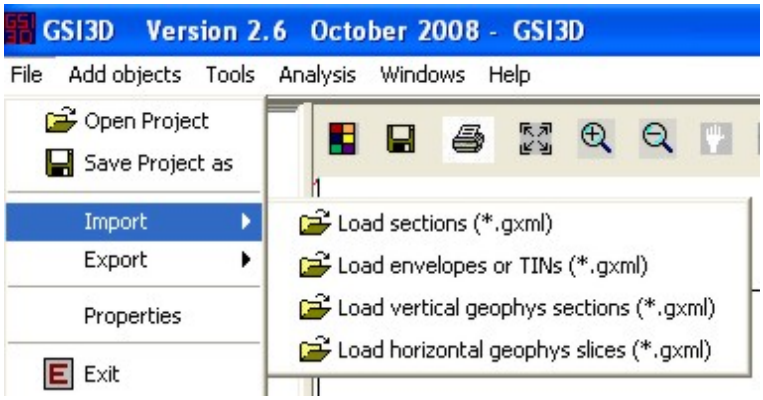
Clicking the **Open Project** option opens a standard dialogue box to navigate and select the *.gsipr Project file required, once a project is loaded this option is greyed out as only a single project can be loaded in a session.

Save Project as

Selecting **Save Project as** enables the project that has been worked on to be saved at the end of a modelling session as a project workspace *.gsipr using a standard explorer dialogue box to navigate to a preferred folder location, name the file and Save.

Import

This function enables the user to select from a series of four import options

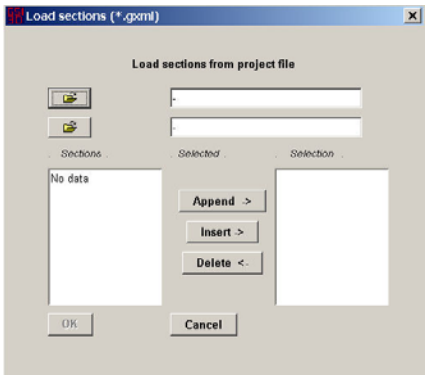


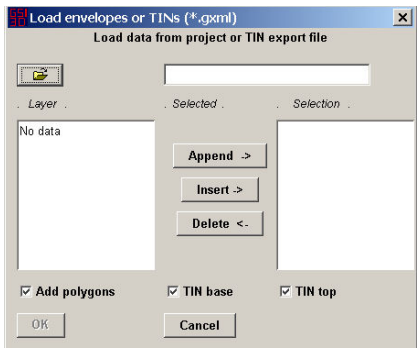
Load Sections (.gxml)*

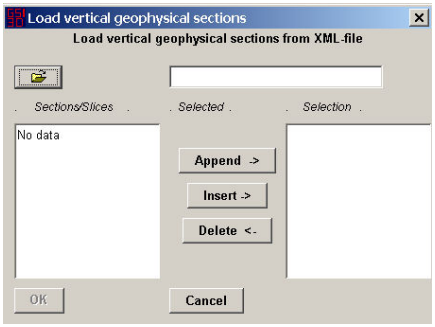
Selecting this option produces the dialogue box below in which clicking the folder buttons requires navigation to and selection of the desired *.gsipr and *.blg files (downhole borehole interpretation file) for the sections. If no boreholes are present in the sections simply selecting any *.blg file will suffice. The sections available are listed in the bottom right box and can be Appended or Inserted or Deleted into the selection box on the left. Once data is selected the Ok button at bottom left becomes bold and clicking on it loads the selected items.

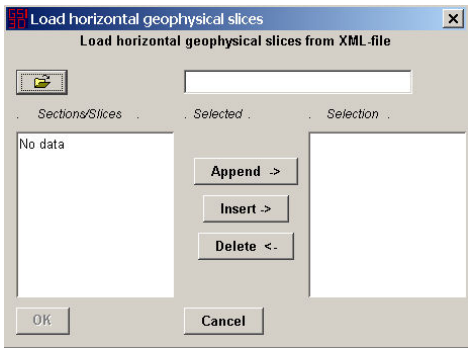
The **Load envelopes or TINs (*.gxml), , Load vertical geophys sections (*.gxml)** and **Load horizontal geophys slices (*.gxml)** options operate in exactly the same way).

NOTE Before envelopes or TINs can be imported the gvs file must be loaded into the project workspace (see under Properties below), if not an error message will appear asking for the GVS file to be loaded.





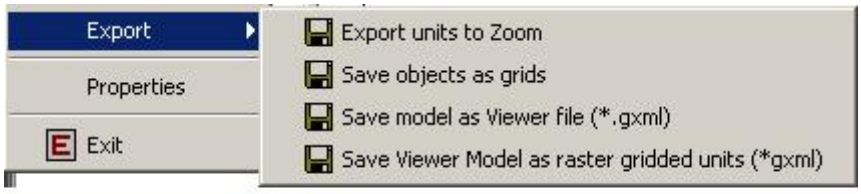




The four import option dialogue boxes are shown above.

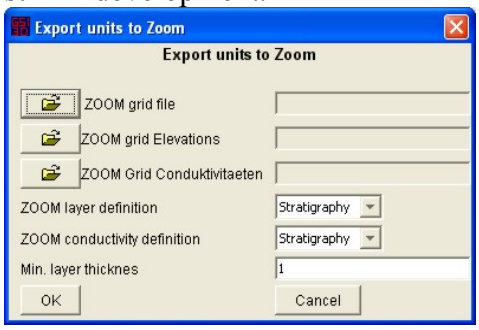
Export

The export menu expands to four options shown below



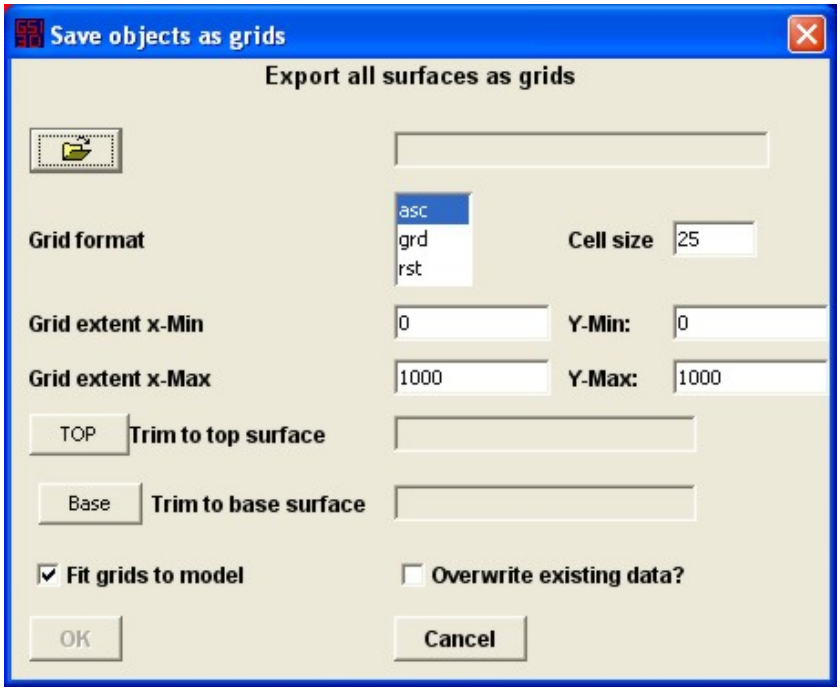
Export units to Zoom

Zoom is being developed by BGS as a groundwater flow modelling application to work in tandem with GSI3D. This dialogue box has been prepared to convert stratigraphic and conductivity data held in the GSI3D model into grids for use in Zoom. At present this function is still in development.

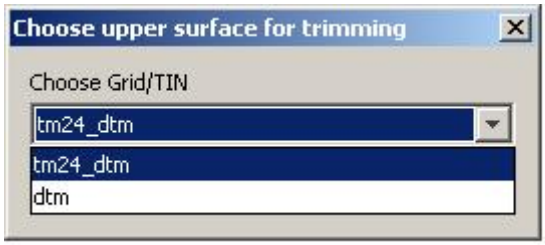


Save objects as grids

Clicking on this option also brings up the standard windows save box enabling the user to save the top, base and thickness (unitname_b for base, unitname_t for top and unitname_th for thickness), of all the modelled units as individual ASCII or surfer grids. This is carried out as a batch job for all the units in the previously calculated model stack. The cell size can be selected and the grid extent needs to be set to fit the required study area for export. Clicking on the folder icon on the top left brings up the standard Windows save dialogue**.**



The trim to top/base buttons enable the user to select a bounding upper or lower surface using a grid/tin selected in the dialogue box below from the list of the already loaded surfaces within the project.

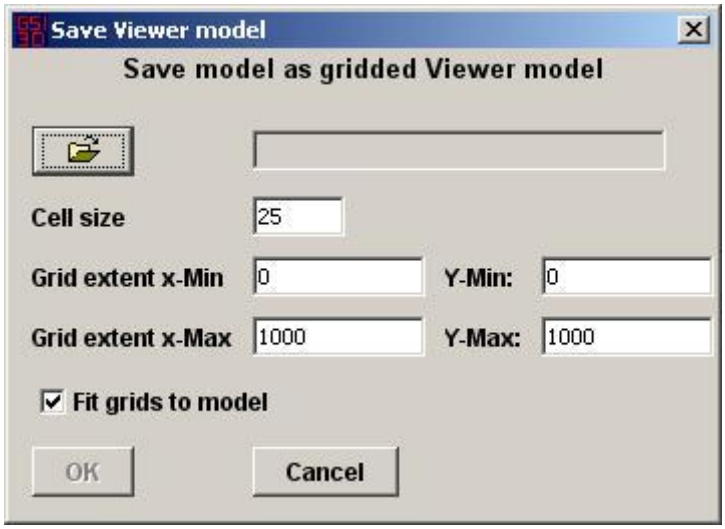


Save Viewer Model *.gxml

This function exports the calculated model as triangulated objects with all attribution specified in the *.gvs file using a standard save dialogue box.

Save Viewer Model as raster gridded units (*.gxml)

This function enables the export of the entire calculated model (volume file) as a gridded raster file ready for use in the Sub-surface Viewer. This functionality is likely to be used at the end of a modelling project as the first stage in setting up the model within the Sub-surface Viewer for delivery to clients. It also serves as needed to decrease the resolution, or thereby file size, of a previously calculated model.

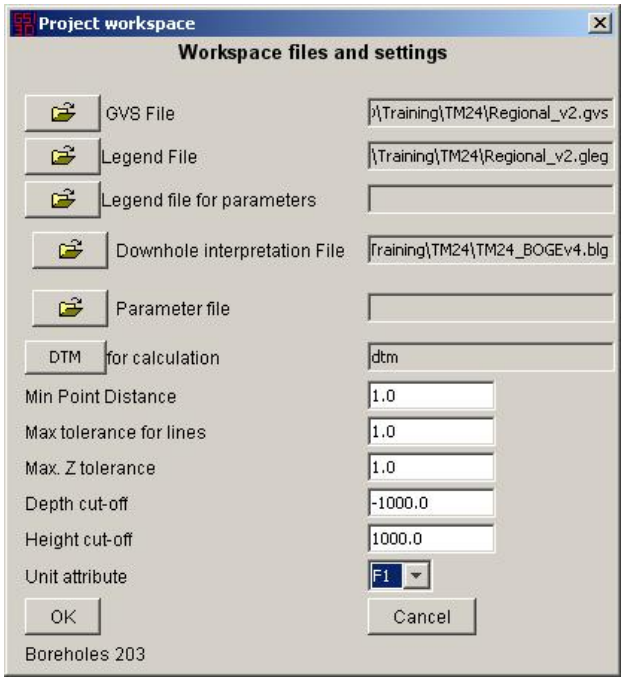


Properties

This important screen is used to define the properties of the workspace that is being used in a session. It contains file selector buttons to specify the essential files for any modelling project including the sequence (*. gvs) and legend (*.gleg) files; the legend file for parameters (*nvleg) the downhole borehole interpretation file (*.blg) the parameter file (*plg) and most importantly the dtm option which defines the surface to be used to cap the model for calculation.

A series of defined tolerances and cut-offs can also be specified together with the attribution of units which is selected from the column headers of the *.gvs file. During a session these parameters can be altered as needed, for example a new *.gvs with an additional unit can be inserted to overwrite an existing gvs, similarly a new dtm can be identified to cap the model for a further calculation.

NOTE: To make these changes permanent the project file must be re-saved



Settings to be specified in metres in the type-in boxes include

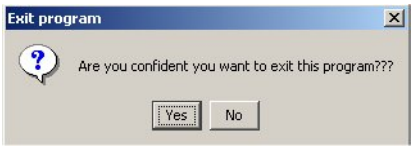
1. Min point distance sets the distance (in x,y) below which nodes will be discarded
2. Max tolerance for lines sets the maximum tolerance for the distance between a lense correlation and the lense envelope (in x,y)
3. Maximum z-tolerance sets the distance (in z) below which nodes will be discarded
4. Depth cut-off for model sets the maximum depth of the model relative to OD
5. Height cut-off sets the maximum height of the model relative to OD

The Unit attribute sets the overall GVS attribute for the project on start by selecting the attribute from the list present in the *.gvs file (here shown as F1.

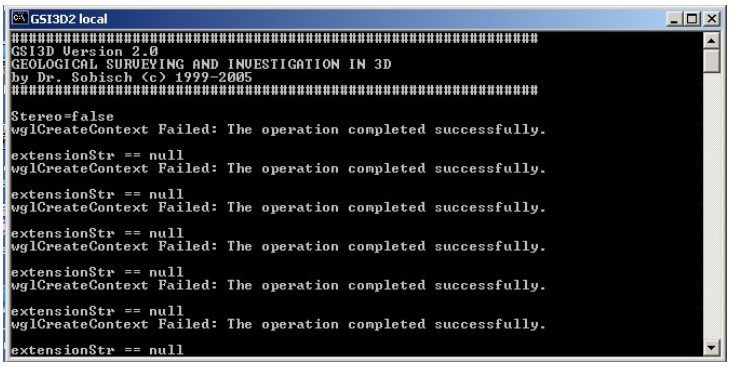
The OK button confirms changes made within session, Cancel discards such changes
The number of boreholes loaded in the project is also listed at the base of the dialogue box.

Exit

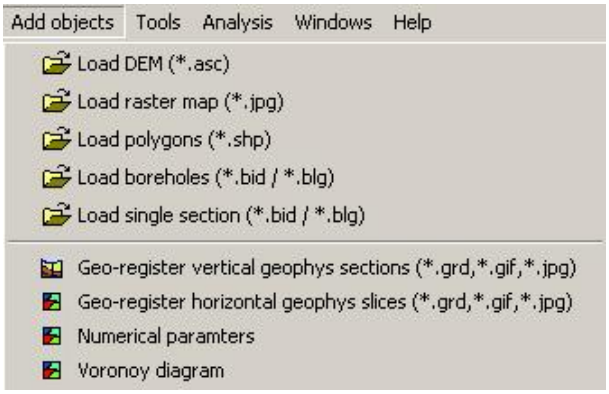
This button exits the application. The user will get one chance to cancel this after that unsaved data is lost. Clicking on the close icon on the GSI3D window has the same effect.



NOTE: Closing the MS_DOS window below will automatically shut down the programme and any unsaved data will be lost!


GSI3D2 local
GSI3D Version 2.0
GEOLOGICAL SURVEYING AND INVESTIGATION IN 3D
by Dr. Sobisch (c) 1999-2005
Stereo=false
wglCreateContext Failed: The operation completed successfully.
extensionStr == null
wglCreateContext Failed: The operation completed successfully.
extensionStr == null
wglCreateContext Failed: The operation completed successfully.
extensionStr == null
wglCreateContext Failed: The operation completed successfully.
extensionStr == null
wglCreateContext Failed: The operation completed successfully.
extensionStr == null
wglCreateContext Failed: The operation completed successfully.
extensionStr == null

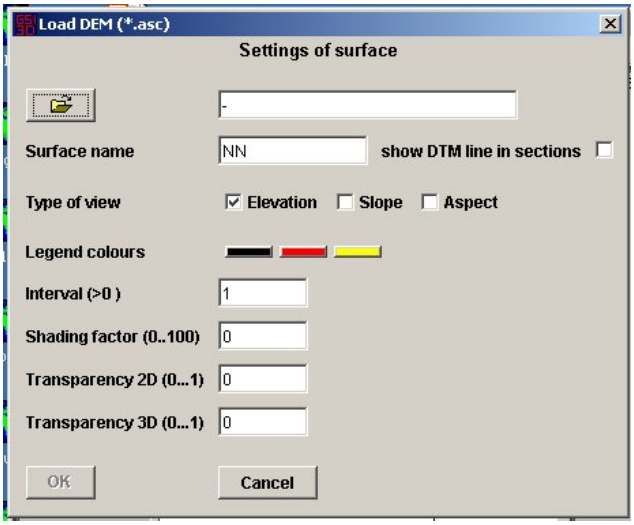
3.1.1.2 Add Objects



This is the main menu for loading modelling data into GSI3D.

Load DEM (*.asc)

Clicking on this option produces the loading and properties box shown below.



Click the *file locator icon* at the top to enable navigation through the file structure to the particular DEM you wish to load. Once located select and open the .asc file and this is loaded into the file box and the file name is inserted into the *Surface name* box. The name can be altered here.
The *show DTM line in sections* box has to be ticked if the grid being loaded is to be displayed in section.
The remaining properties enable various methods of adjusting and enhancing the display of the DEM and can be experimented with to produce the preferred effect.
Finally click *OK* to load the DEM that should then appear fitted to size in the map window.

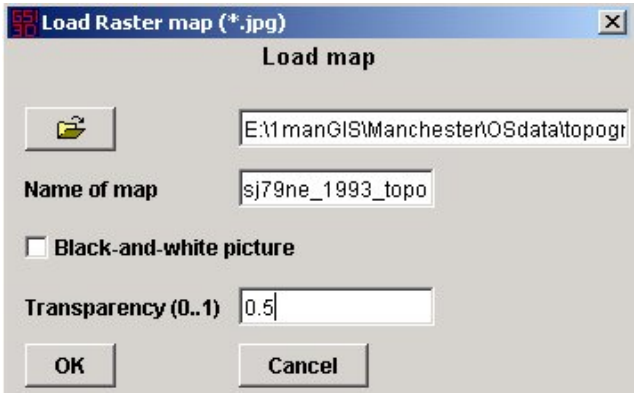
Common DEMs so far used in GSI3D include those provided by the OS, CEH and Environment Agency LIDAR data, Getmapping NEXTMAP data. Bathymetric data can also be uploaded to

GSI3D and must be combined using a GIS with land surface data for studies in coastal areas and inland water masses.

NOTE: The DTM loaded through this function is used for visualisation and section correlation only. The DTM used for model calculation is loaded directly to the geological unit stack and this is described in Sections 3.2.2 & 4.6

NOTE: Please see the Section 6.2 for the various definitions for DTM, DEM and DSM as used in this manual.

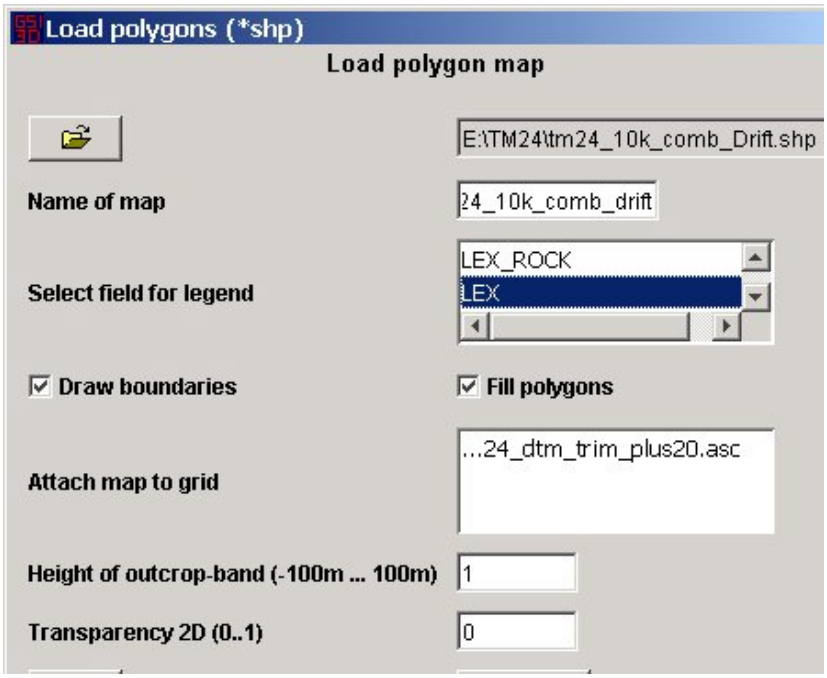
Load raster map (*.jpg)



Clicking on this button produces the properties box shown below. Click the *file locator icon* at the top to enable navigation through the file structure to the particular digital map file you wish to load. Once located select and open the .jpg file and this is loaded into the file box and the file name is inserted into the *Name of map* box. The file name may be changed here if needed.

Check the *Black and white picture* box if appropriate and adjust the *Transparency* setting to suit. Then click *OK* and the file will load into the map window.

NOTE: The JPEG file must be accompanied by a *.jpgw registration file, see Section 2.1.2



Load polygons (*.shp)

Clicking on this button produces the load polygon map dialogue box.

Click the top *file locator icon* to enable navigation through the file structure to the particular digital map file you wish to load. Once located select and open the .shp file and this is loaded into the file box and the file name is inserted into the *Name of map* box. The file name may be changed here if needed.
The *Select the field for legend* box displays the attributes of that particular shape file such as LEX for Stratigraphic Lexicon entry and ROCK for lithology in case of BGS DiGMapGB shapes.

Tick the *Draw boundaries* and *Fill polygons* options to show the coloured envelopes.

In the *Select grid to attach .shp file* box all the DEMs that are loaded are listed, it is important to highlight and select the correct DEM that corresponds to the geographical location of the .shp file (e.g. surface geological map with DTM and bedrock map with rockhead). This enables the user to visualise the crop lines in the section view. This is an elementary function in GSI3D because it allows the integration of 3-D subsurface data with outcrop mapping (2-D) .

NOTE: a DTM covering a larger area than the individual .shp file can be used, and several .shp files can be loaded to tile the area of a large DTM. GSI3D however becomes confused if you try to load multiple .shp files (e.g. 25K tiles) and then register them to more than one DTM (e.g. corresponding 25K DTM tiles). It is thus advisable to have DTMs available for the complete project area as well as tiled DTMs if modelling is proceeding on a sheet-by-sheet basis. This way individual sheets 10K, 25K, 50K etc can be modelled and deposited in corporate data stores whilst bespoke project areas and regional compilations can also be viewed as a whole in the GSI3D map window.

In the *Height of outcrop-band* field the user can set the vertical height in metres for the display of the polygon theme (usually the geological unit at outcrop) along the DTM on the line of section. This facility aids the drawing of sections by producing bands of colour along the DTM surface trace using the same colour scheme as in Legend file. Inserting a positive values colours up a band above the DTM trace, a negative height value colours up the band below the DTM trace.

Adjust *Transparency* to suit from 0 to 1. Default is 0 a solid colour, we recommend a setting of 0.5 if a degree of transparency is required.

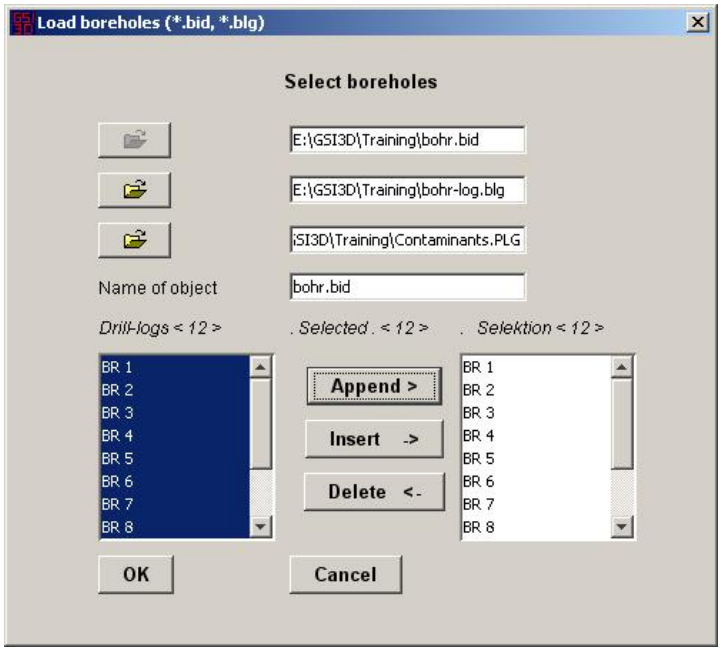
Click *OK* and the map polygons will display in the map window.

Load boreholes (*.bid / *.blg)

Clicking on this option produces the borehole-loading screen.
Click the two separate *file locator icons* to enable navigation through the file structure to the two borehole files needed (Index and Log).

The upper file selector requires the *.bid index file listing the unique borehole number, coordinates and start height. This file is the master table and is automatically listed in the *Name of Object* box, all the boreholes in this table are also automatically listed in the borehole field. The second file selector requires a *.blg downhole log file giving properties such as stratigraphy, lithology, colour etc together with depths to the base from the start height (not reduced levels).

Both these datasets are readily downloaded from the BGS SOBI and BoGe databases using the BGS Data Portal (see Sections 2.1.4 & 2.2). The third file selector is to load parameter data relating to the boreholes for example chemical analyses performed on samples at particular depths in the boreholes. The *Name of object* by default displays the borehole index file name which can be altered if required.

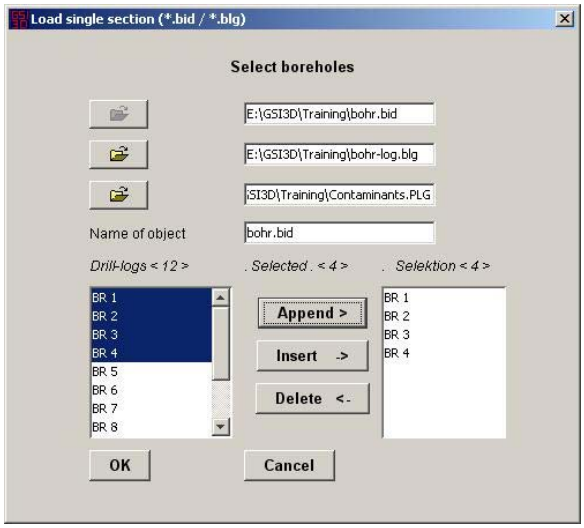


The selected boreholes display their unique identifier in the *Boreholes* box. Highlighting one and pressing Ctrl-A selects them all, otherwise select those required. Editing of the borehole list is made possible through the *Append*, *Insert* and *Delete* buttons. Once the required boreholes are all listed in the *Selection*, click *OK* and they are loaded. Boreholes are plotted relative to the DTM in the map window, those with simple location details colour red (SOBI only) whilst those with downhole coded units (i.e. suitable for modelling) are coloured black and green depending on their total depth (see Section 3.2.2)

*Load single section (*gxml)*

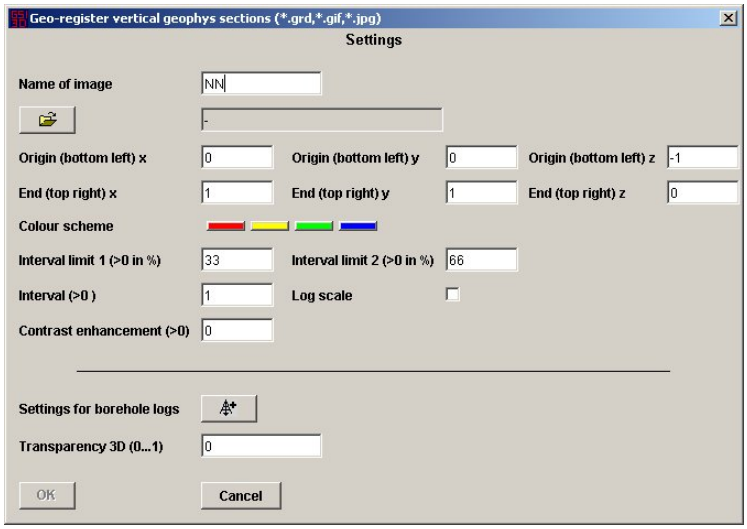
This button opens the borehole-loading screen as explained above. Selecting borehole locations from a borehole index file (*.bid) individual sections can be created directly 'free hand' or from a pre-selected set of boreholes that make a section.

NOTE: The points will be connected to a section as listed in the *Selection* list on the right, so the user must add the borehole string in the correct order.



Geo-register vertical geophysical section

This option allows the geo-rectification of vertical geophysical sections using the following dialogue box



Next to the usually visualized basic elements, geophysical vertical sections can be visualized in the section and 3D windows. Before loading the sections it is suggested to load these basic elements, as the dem.asc, map.jpg, logs.bid and layer.blg.
In order to display geophysical vertical sections in 2D and 3D, they have to be geo-registered, by defining the lower left and upper right coordinates in the x, y and z direction.

Click the top file locator icon to navigate through the file structure to the selection you want to geocode. This can either be a picture or a grid file (*.gif, *.jpg, *.rst, *.asc or *.grd). Type in the Settings property boxes the coordinates for the *Origin (bottom left) x*, *End (top right) x*, *Origin (bottom left) y*, *End (top right) y*, *Origin (bottom left) z*, *End (top right) z*. In case a *.rst, *.asc or *.grd file is loaded you can define the *Colour scheme* (in the usual way of changing colour settings), the *Interval limit 2 (>0 in %)*, *Interval (>0)*, the *Contrast enhancement (>0)* and check the *Log scale* box if appropriate.

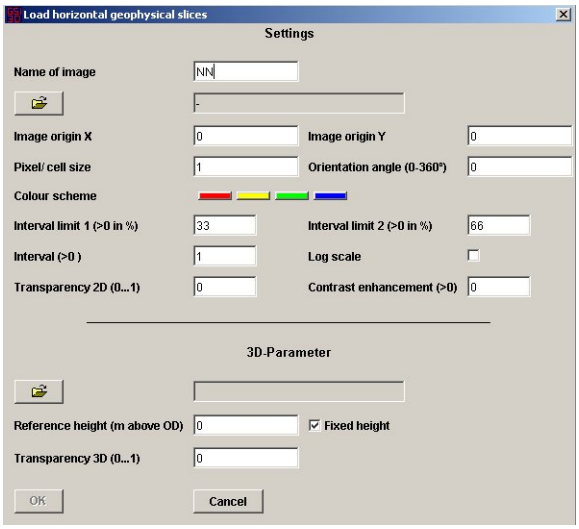
Clicking the *Settings for borehole logs* button below opens the property box for *Drill-log layout settings*, which can be changed any time during the working session.
Click *OK* and the vertical geophysical picture or grid appears in the cross-section file tree of the map and profile view in the same way like any other geological cross-section, as well as the extension line of the section in the map view.
The sections can be linked to the 3D view and stored in the *.gxml project file.

NOTE: The coordinate setting properties can only be changed before the first visualization of the slice, not during the first or any other working session.

NOTE: The project *.gxml file only stores a link to the geophysical picture or grid, referring to the location of the respective picture or grid while geocoding. Changing the location of the picture or grid into another folder will result in loss of the data for the picture or grid. But if these files are in the same directory as the *.gxml project file the system automatically checks this directory and chooses the indicated picture. This enables the transfer of the complete folder (*.gxml and slices) into a differing directory environment.

Geo-register horizontal geophysical slices

This option allows the geo-rectification of horizontal geophysical slices using the following dialogue box



In addition to the display of vertical geophysical sections it is also possible to visualize horizontal geophysical slices in the map and 3D windows. Before loading the slices it is suggested to load the basic elements, as the dem.asc, map.jpg, logs.bid and layer.blg.
In order to display geophysical horizontal slices as maps and in 3D, the slices have to be geocoded, by defining the lower left corner and the pixel or cell size (m/Pixel) of the slice.

Click the top file locator icon to navigate through the file structure to the slice you want to geocode. This can either be a picture or a grid file (*.gif, *.jpg, *.rst, *.asc or *.grd). Type in the *Settings* property boxes the coordinates for the lower left corner *Image origin X* and *Image origin Y*, as well as the *Pixel/ cell size* in m/Pixel. If necessary, you can change the angle of the slice in counter-clockwise orientation from the North-South direction, by filling in the setting box

Orientation Angle (0-360°). If a *.rst, *.asc or *.grd file is loaded you can define the *Colour scheme* (in the usual way of changing colour settings), the *Interval limit 2 (>0 in %)*, *Interval (>0)*, the *Contrast enhancement (>0)* and check the *Log scale* box if appropriate. For both, pictures and grids you can now or at any point later in the working session choose the *Transparency 2D* settings.

The lower part of the properties box is restricted for the definition of the *3D-Parameter* of the horizontal slice, either connecting the elevation of the slice in relation to the DTM or giving an absolute height above or below mean sea level. In order to link the slice to the DTM use the file locator icon to navigate through the file structure to the appropriate dem.asc and define the relative distance of the horizontal geophysical slice to the surface in the settings box *Reference height (m above 0D)*, the *Fixed height* box in the same line turns automatically off in this case. In case the slice was taken as a plain slice with an absolute height related to sea level only, define this elevation in the *Reference height (m above 0D)* box. These absolute settings can be modified any time during the working session. If necessary choose the *Transparency 3D* properties.
Click *OK* and the horizontal slice appears as a map in the file tree of the map window.

The geocoded and displayed horizontal geophysical slices can be stored in the *.gxml project file.

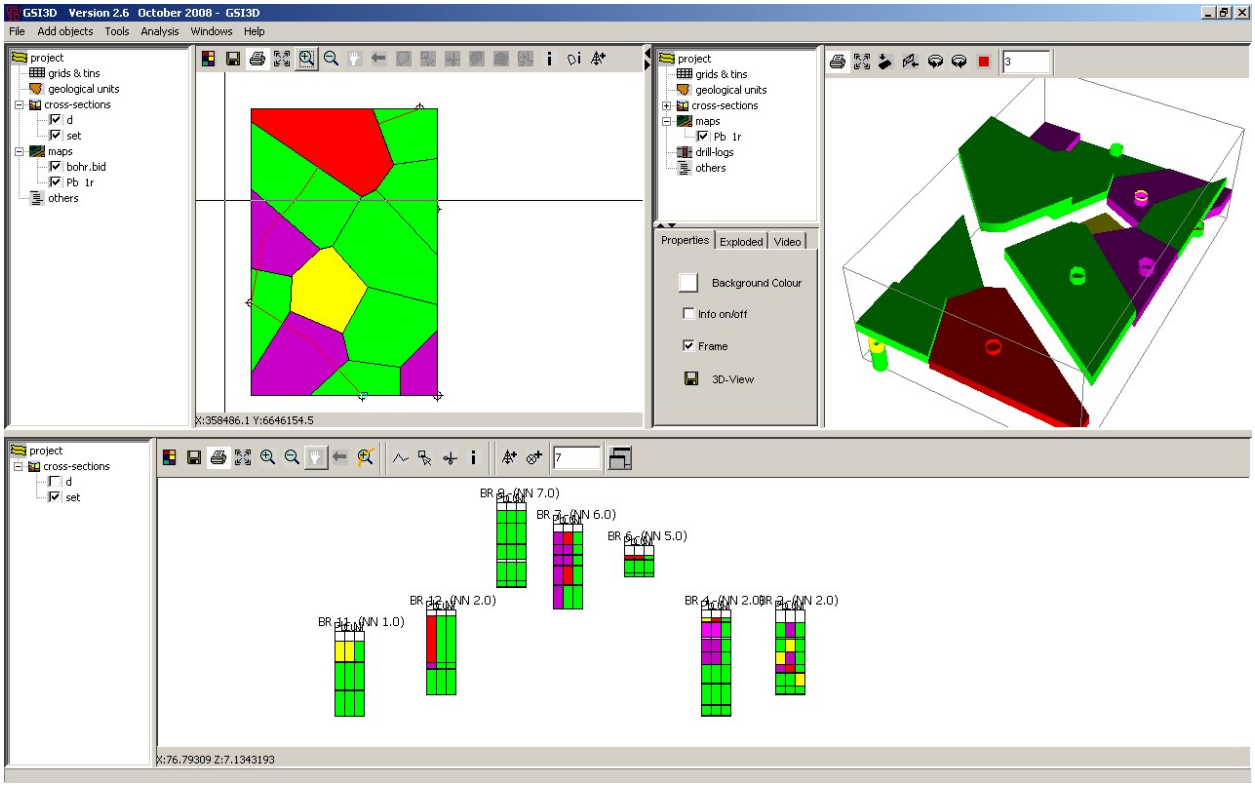
NOTE: The coordinate setting properties can only be changed before the first visualization of the slice, not during the first or any other working session.

NOTE: The project *.gxml file only stores a link to the geophysical picture or grid, referring to the location of the respective picture or grid while geocoding. Changing the location of the picture or grid into another folder will result in loss of the data for the picture or grid. But if these files are in the same directory as the *.gxml project file the system automatically checks this directory and chooses the indicated picture. This enables the transfer of the complete folder (*.gxml and slices) into a differing directory environment.

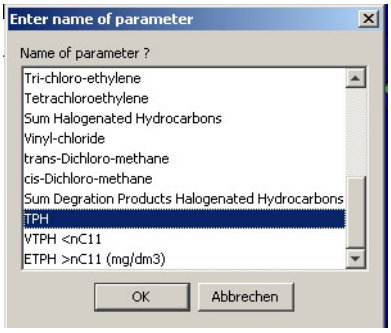
For case studies of the use of geophysical data in GSI3D also see Williams & Scheib, 2008.

Numerical parameters

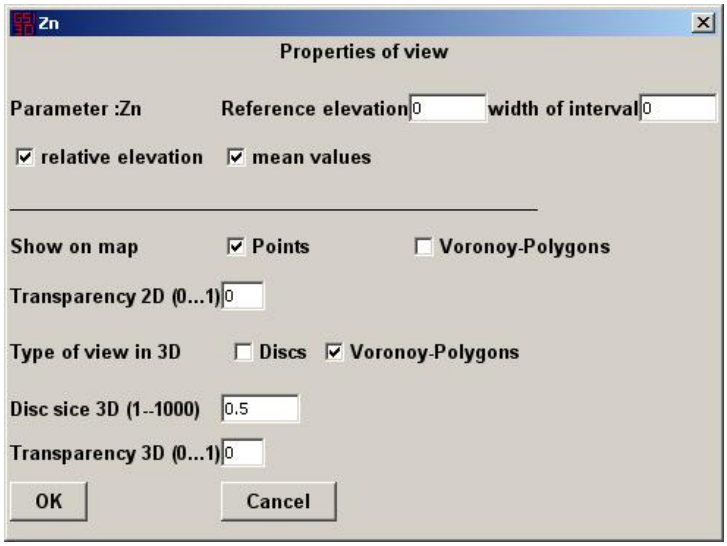
It is possible to display colour-coded values of the numerical parameters at in the subsurface in the map, section and 3D window as shown below



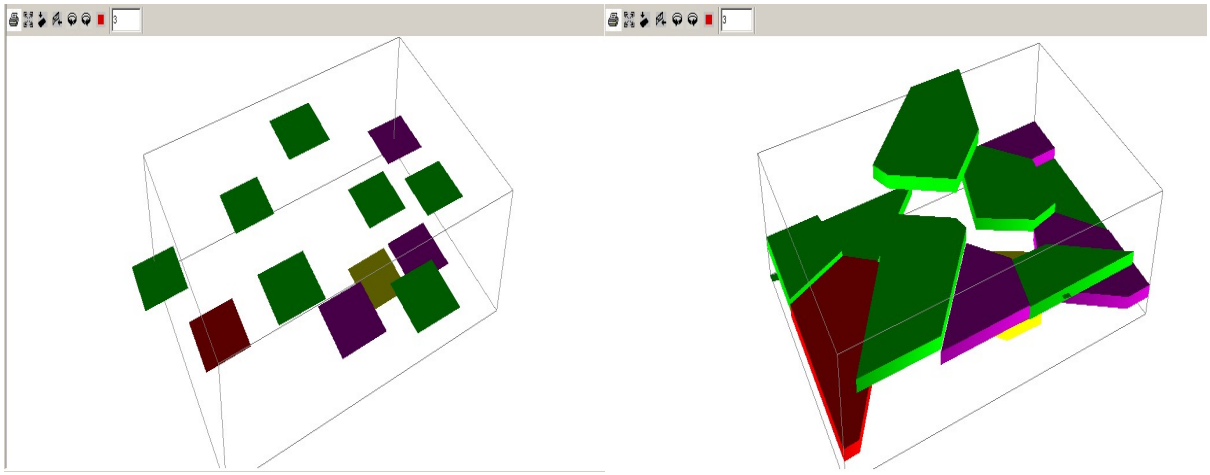
After loading the data as described above. The user can set the parameter display under Add Objects> Numerical Parameters. This bring up a dialogue box to choose the *Name of parameter* (see below), where all loaded numerical point parameter data from the *.plg file are listed.



The subsequent dialogue box defines the 2D and 3D *Properties of view* for the chosen parameter (see below). It is either possible to display a relative *reference elevation* to the used DTM, or, by ticking off the *relative elevation* box, to choose an absolute elevation. You can also define the *width of interval* of the parameter on display in meters, and if so you have the possibility to get a calculated *mean value* for the specified interval by ticking the respective box on or off.



The lower part of the dialogue box allows to set the 2D and 3D properties. You can *Show on map* the parameter distribution either as Points or Voronoy-Polygons (see below) by ticking the suitable box and set the *Transparency 2D (0-1)* values. At this stage you can also set the Type of view in 3D, by choosing *Discs*, *Disc size 3D (1-1000)* or *Voronoy-Polygon* as well as *Transparency 2D (0-1)*.



Click *OK* and the defined distribution map appears in the map folder in the Table of Contents. Here the chosen map name is displayed with an extension, stating if the plot has a relative *(r)* elevation to the DTM or an absolute *(a)* elevation.

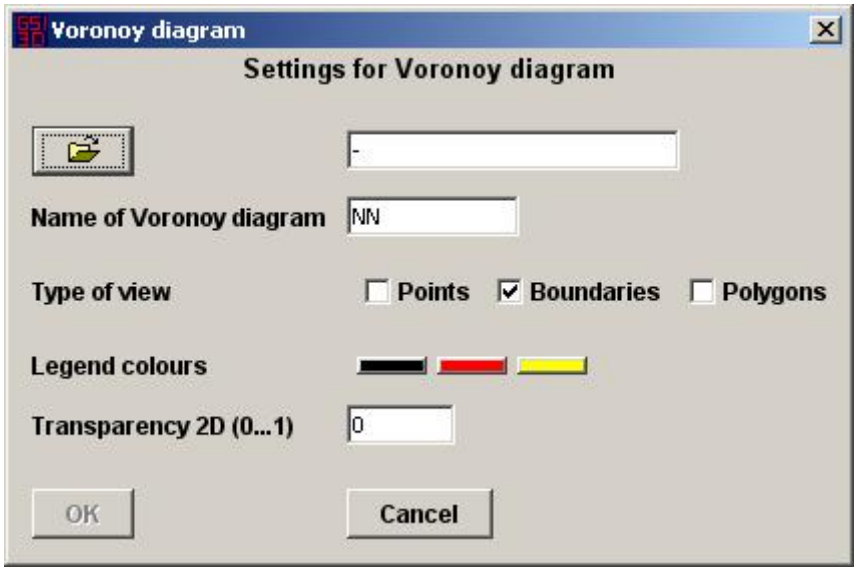
NOTE: The default for the map is *Voronoy-Polygon*, even if *Points* is ticked before the first loading process.

NOTE: These 2D and 3D settings can be changed any time during the working session by a right click on the object .

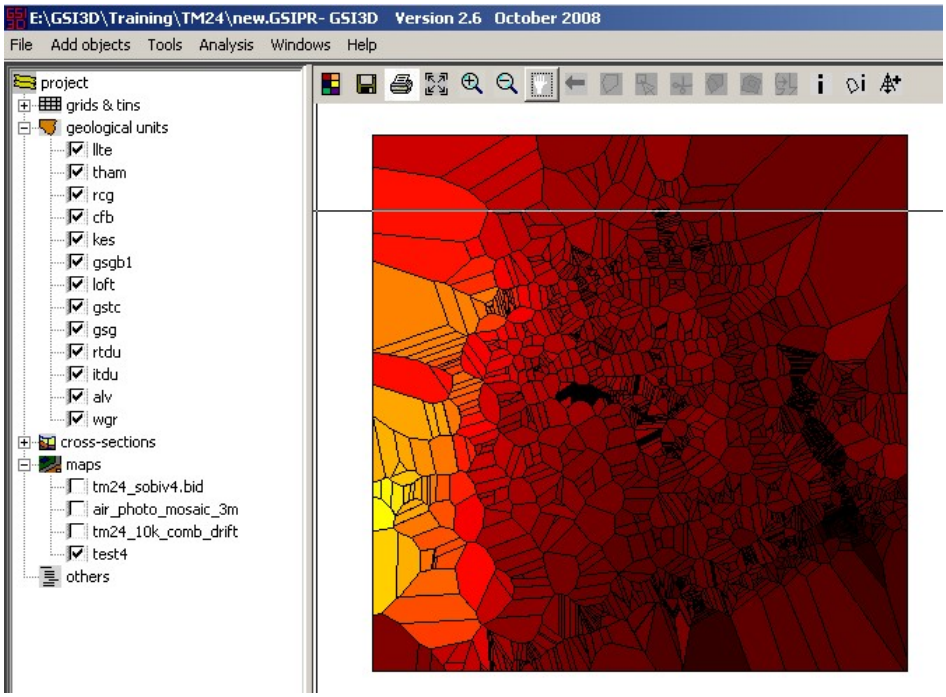
Voronoy diagram

Clicking on this option brings up the following loading screen (below), enabling the user to load a set of point data in the *.dat format (see Section 3.2.2) to be displayed as a Voronoy diagram (also below). The settings for the Voronoy Diagram include the choice to display either points,

boundaries or coloured polygons. This function is useful to display properties within a map view and also draped in 3D.



Once created the Voronoy map is listed in the Map folder of the Table of Contents (see below at Section 3.2.2)



Example Voronoy map in the map window

3.1.1.3 Tools

This menu point contains a selection of different tools and functions used in the modelling process.

Create new section

Selecting this item leads to a dialogue box requesting the input of a unique identifier *Name of section* for the section to be constructed. Be systematic in labelling sections making use of the sheet on which they occur and their direction and sequential number where possible e.g. TM14_NS2 is the second north-south aligned section on the TM14 25K tile. Once selected this section appears at the bottom of the list of sections in the table of contents of the sections window and is ticked as the active section enabling construction to commence. Use this option to draw new sections and to add sections to the existing ones.
This function is used to specify the alignment of synthetic sections, once the model is completed as described in Section 4.9.2.

NOTE: Always open all existing sections and envelopes prior to creating new ones so that all the sections and envelopes will appear in the saved .gxml file at the end of the session. GSI3D only stores what is loaded at the time saving is executed and doesn't automatically append data from previous sessions.

TIP: This function is also used for creating synthetic sections

Create new geological unit

This button creates a geological unit from correlated sections by plotting all base points in the map window, ready for the user to draw the required envelope. When selected it presents a *Selection of unit* window listing *Name of unit* for all units listed in the .gvs file. Select the unit required to commence drawing an envelope for it (see below).

NOTE: Once a unit has been created and at least one envelope has been drawn, it will be stored in the project file with the next save. This is not the function for calculating the z values of the envelope (see Section 3.2.2).

Create new TIN

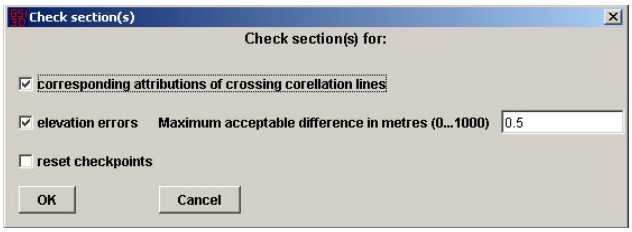
Selecting this option produces a dialogue box to name the TIN
Multiple Tins can be created and are stored in the *.gsipr file, the one to be used for calculation is defined and stored in the Workspace properties settings. This produces an empty object in the grids and tins folder. The TIN is created by the procedure described below in Section 3. 2. 2.

Create horizontal slice

This function enables the geological model to be sliced at a defined flat vertical elevation, creating a horizontal slice through the ground to produce an "uncovered" geological map.

Once generated these slices are added as objects to the map folder in the Table of Contents of the map window

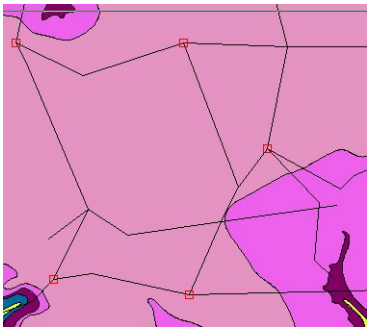
Check all sections



This function enables the user to check all loaded sections for:

Corresponding attributes of crossing correlation lines which checks the consistent labelling of intersecting lines and for *elevation errors*, which checks for corresponding elevation of intersecting lines according to a defined tolerance setting under *Maximum acceptable difference in metres*

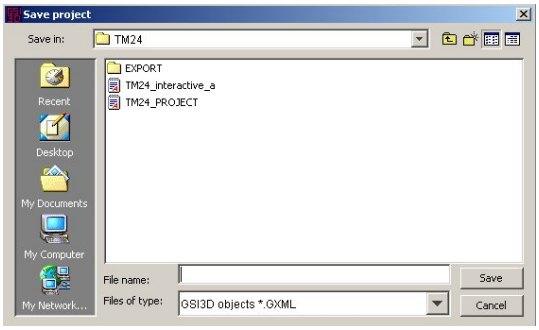
Errors are highlighted in the map window as a red square at intersections. Right clicking on the section allows the user to jump to the error in the section window and to rectify the inconsistency



Checking the *reset checkpoints*
box and hitting ok clears the map window of error indicators.

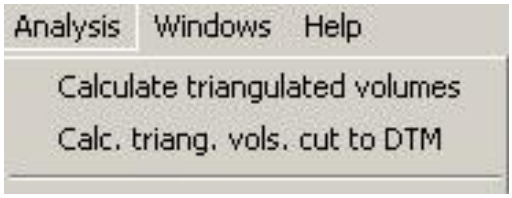
Trim project by area

This function enables the user to trim all sections to a new project area by simply loading the area as a shape, clicking on the cutting polygon with the info tool and hitting the *Trim project by area* button. This creates a new *.gxml file containing all trimmed sections using the dialogue box below.



3.1.1.4 Analysis

The Analysis pull down menu is shown below

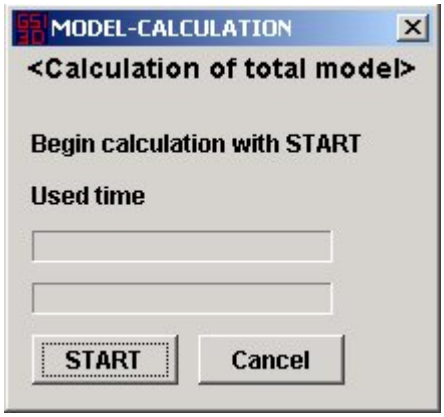


NOTE: Before calculating volumes switch off editing on all geological units!

Calculate triangulated volumes

This function starts the calculation of all geological objects as Triangulated Irregular Networks (TINs). This process calculates all tops, bases from loaded sections and envelopes. Walls are calculated where the unit extends beyond the edge of the area to be calculated which is specified by the DTM. (see Section 3.2.2 for dtm trimming)

After selecting the *Calculate triangulated volumes* option the following dialogue box appears:



Simply press Start and watch the model calculate until the Start button becomes "OK". Hit OK and the calculated TINs are added to the geological units in the TOC and can be displayed in the Map Window by changing the Properties or in the 3-D Window by linking across.

Calculate triang(ulated) vol(ume)s cut to DTM

This option also calculates the entire model as above, however any geological units occurring above the DTM (due to errors or in cases of palaeo-reconstruction) will be deleted from the model.

3.1.1.5 Windows

Borehole Viewer

Clicking on this option activates the single borehole viewer window. The viewer displays borehole logs selected by the Info tool from the map and section window and is particularly useful in deciding which boreholes to incorporate during section construction.

NOTE: The borehole viewer runs in a separate window to GSI3D and once opened it must be dragged to a convenient position within the monitor window. Also the first log selected using the info tool will need to be rescaled and positioned for viewing.

Display Java Console

Clicking on this option calls up the Java Console that contains details of the status of the software including any error messages that have occurred during the session. This facility should be used to alert the developer of any programme errors by cutting and pasting the message from the Java window into a text file and then e-mail it to 3dmodels@bgs.ac.uk.

TIP: It is useful to have this window open at all times, to instantly see when errors occur

Split windows

This function enables the user to split or float all windows and arrange them in any desired order, this is especially useful when working just in the map or section window.

Once the windows are floating they can be docked again or shut down and activated again using the options below that replace the *split windows* button when it is utilised.

3.1.1.6 Help

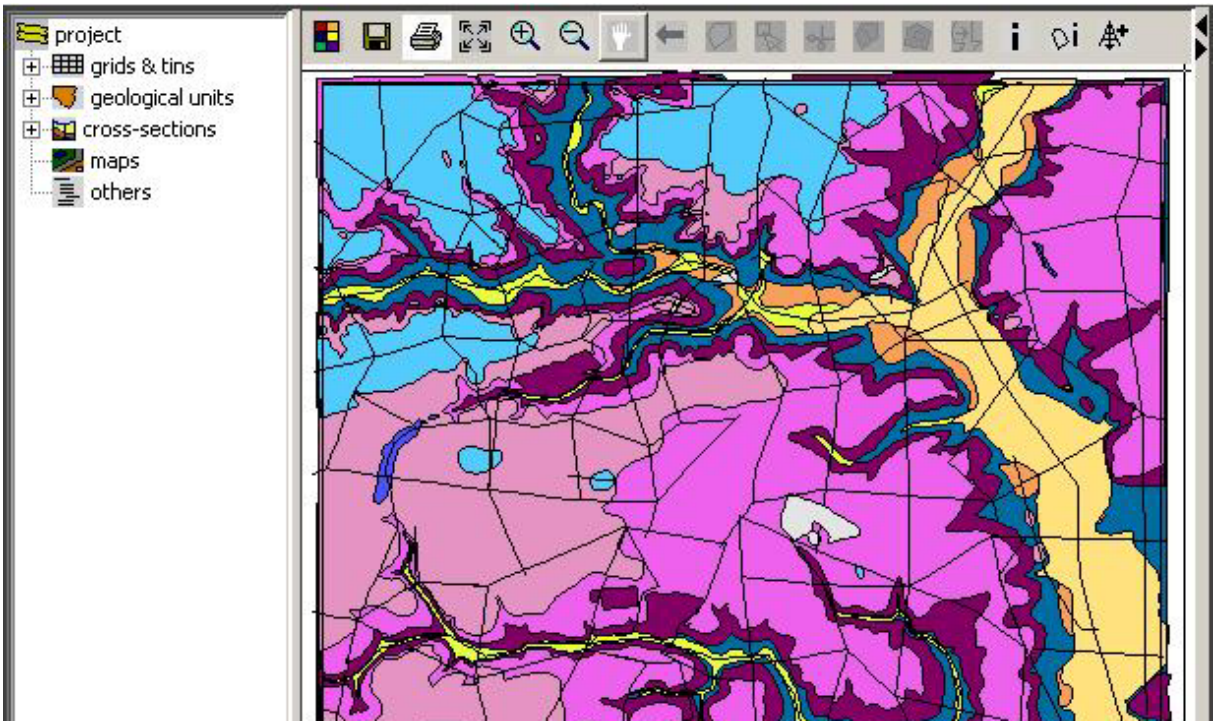
The ***About GSI3D*** button contains the developer's details and will in future releases include a link to user support derived from this manual.

License, opens a dialogue box to enable users to enter their details and password key to make the software fully operational, without such activation the software only performs as a demo version.

Project Information is a Java console listing details of the model

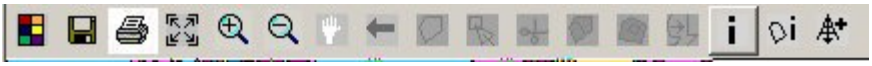
3.2 The map window

An example map window is shown below



3.2.1 Toolbar

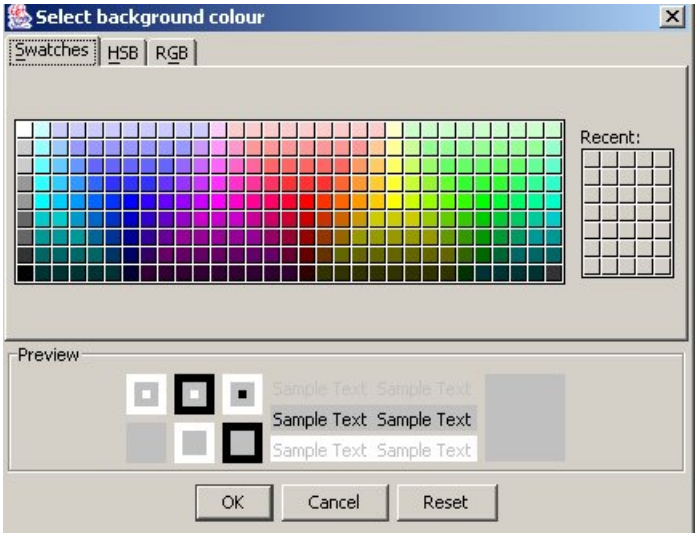
The toolbar contains the following icons:



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

1. Select background colour

Click brings up the dialogue box below to select a suitable background colour in 3 different ways:

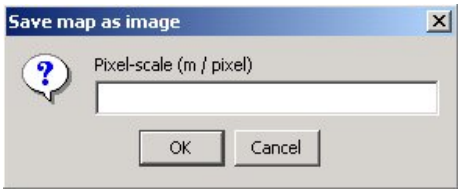


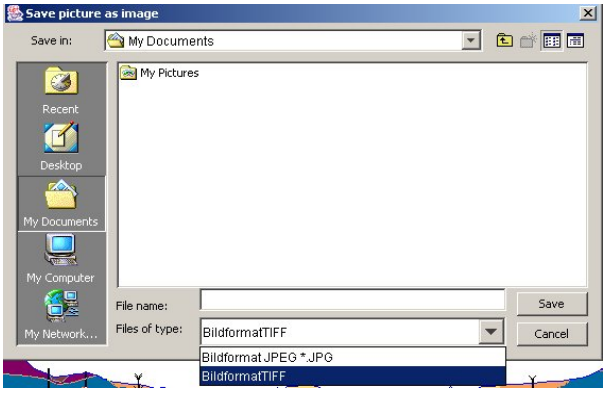
The Swatches tab shows 270 colour tiles, the HSB (Hue, Saturation, Brightness) and RGB (Red, Green, Blue) tabs allows selection by interactive slider bars.

TIP: This function is useful when constructing a bespoke Legend file

2. Save map window as image
Saves the contents of the map window as a geo-registered jpeg or tiff image

Click this option to get the dialogue box asking for scaling for the image, insert an appropriate m per pixel spacing to determine the definition of the image, then save the image as a *.jpg or *.tif in a location of your choosing.





When saving a registration file is generated automatically (*.jpgw or *.tfw), enabling the import of the map to GIS systems.

The table below show the required values to export the images at different scales for a typical print resolution of 300 pixels per inch (ppi).

SCALE	M/PIXEL
1:50000	4.23
1:25000	2.12
1:15000	1.27
1:10000	0.8462

NOTE: When drawing a section containing no correlation line the capturing mode does not function properly – the solution is to insert very small correlation lines at the base and top of the section to make the system think that there is something to capture.

Click fits the whole object to the extent of the map window

3. Print Map Window
Click on this icon to print the map window to a printer

4. Zoom to full extent
Click fits the whole object to the extent of the map window

5. Zoom In
Click on, then click in window and hold down whilst dragging mouse to construct a marquee around the area to zoom in to, release on completion

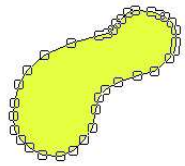
6. Zoom Out
Click on, click in window, and repeat to incrementally reduce the magnification. This tool cannot draw a box to zoom out to a specified area.

7. Pan
Click, then click in window and hold, drag to new position and release, drag and drop.

8. Back to previous view
Click, displays previous views, useful in scale changes, (not an undo button though).

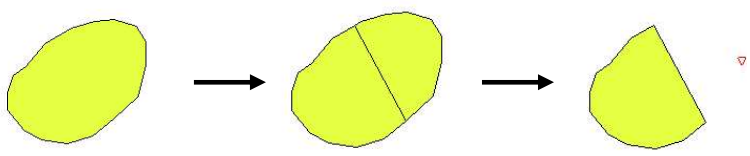
9. Construct Polygon (only active if unit is active in table of contents)
Enables the construction of a new polygon during envelope building,
Click to activate, click at start position, and then click to add nodes to make shape double click close to the first node to complete

10. Node editor (only active if unit is active in table of contents)
Mainly used in editing polygon shapes or dragging nodes to overlap adjacent polygons to enable combination.
Click to activate, right click to select any polygon, displays all existing nodes. Enables addition of nodes to line by clicking on it and removing nodes by double clicking on them.

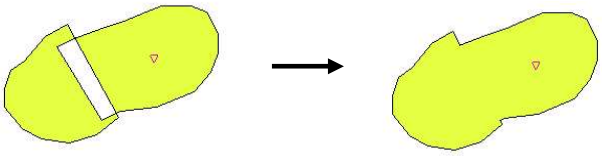


11. Split Polygon (only active if unit is active in table of contents)
Very useful for chopping away chunks of a polygon during the construction of envelopes.
Click to activate, click at point outside polygon to start a line for splitting, then drag to beyond other side of polygon and double click to produce a line crossing the polygon splitting it in two.
Then use polygon info tool (see below), click on it to activate it, then right click on any segment of line in the half of the polygon you wish to be deleted, and select delete polygon from pull down menu, finally confirm your decision.

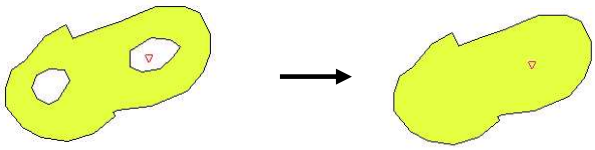
NOTE: When splitting a polygon the initial and final clicks that define the cut line must be within the same polygon. A cut line cannot be produced by starting the cut line in one polygon traversing a second to terminate in a third polygon i.e. A-B-A works A-B-C does not.



12. Combine overlapping polygons (only active if unit is active in table of contents)
Click, automatically combines any polygons in the editable layer that overlap each other. Useful for the drawing of envelopes that include surface outcrops and subcrops.
TIP: Use this tool with care as results can't be undone



13. Combine adjacent polygons and fill holes (only active if unit is active in table of contents)
Click, automatically merges all selected polygons with common (mutual) boundaries and incorporates (deletes) all polygons totally enclosed within those selected polygons i.e. fills islands-holes. Useful for combining polygons of all overlying units in the construction of envelopes of partly or largely concealed strata. It is important to select all polygons to be combined to form the envelope first then click this button, any holes in the distribution should then be cut out (deleted) using the Info (select) and then Select Polygon functions in the normal way.
TIP: Use this tool with care as results can't be undone



14. Clean polygons (only active if unit is active in table of contents)
Click, the tool automatically cleans up coinciding nodes from two separate polygons along mutual boundaries. It also cleans polygons according to the Minimum node spacing (see Section 3.1.1.3)

NOTE: this often is the case with DiGMapGB data spread over more than one map sheet
TIP: Use this tool with care as results can't be undone

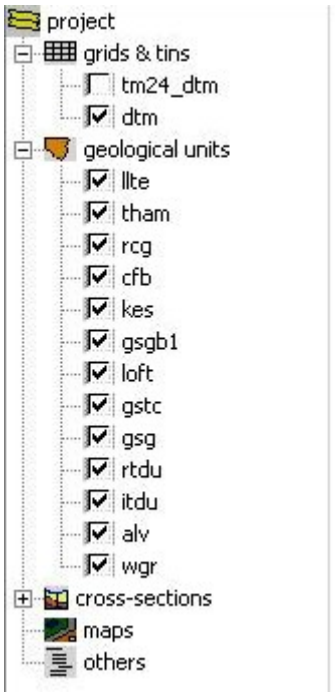
15. Info tool
Click to activate, position the cross hair on the object you wish to interrogate, then use right click to query properties of polygons, grids, boreholes, sections.
For right 'mouse clicks' see Section 3.2.3.

16. Insert selected polygon (only active if unit is active in table of contents)
After selecting a polygon using the Info tool the polygon can be incorporated into the envelope (layer data) by clicking on this button. The info tool leaves a red triangle in the map view to help you visualise which polygon has been selected. When importing intricate polygons the Minimal Point distance must be set to 0 in order to avoid slivers of *no data* (see Section 3.1.1.3)

17. Synthetic log

This button is only active once geological objects (volumes) have been calculated and enables the creation of synthetic logs displayed in the borehole viewer. After activating the button, the user clicks anywhere within the modelled area displayed in the map window in order to instantly display a predicted geological sequence at that point in the borehole viewer.

3.2.2 Table of Contents

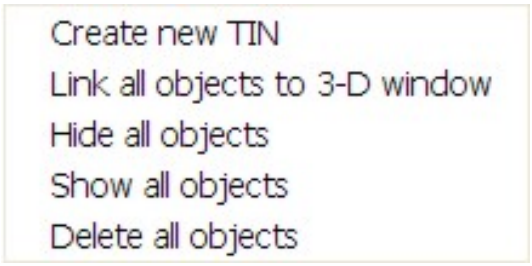


Double click on the project icon to view the layers loaded into the map window, these are arranged into five standard folders. The folders display a plus sign to their left when data is present, clicking on the + expands the folder and changes the symbol to - , click on – to collapse the folder. Individual objects can be switched on and off using standard tick boxes as with GIS layers. Right clicking on any folder icon-name produces menus for reordering the layers and where appropriate editing them or calculating their properties. The following four options are available for every folder, in some cases additional functions are offered and these are discussed in the individual folders descriptions below.

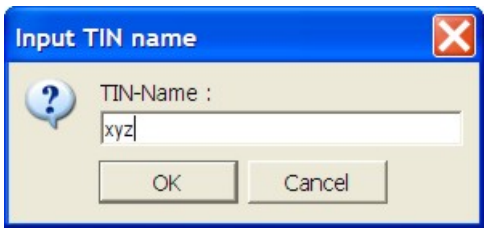
Link all objects to the 3-D window This function enables all the objects within the given folder (grids, units etc) to be added to the 3D window.
Hide all objects (in the map window)
Show all objects (in the map window)
Delete all objects (from the active session)

The folders for the various types of map data are :

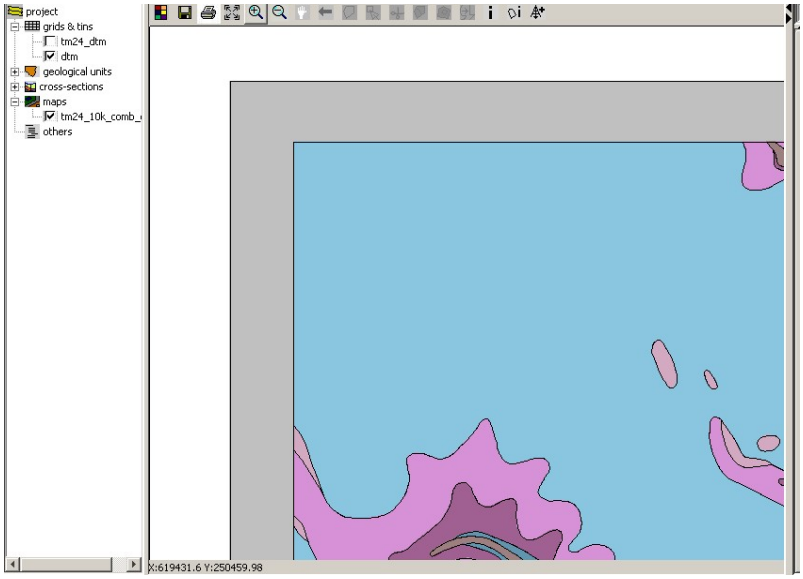
1. grids & tins Contains DTM and other imported surfaces (as raster grids or TINs). The individuasl objects are not distinguished in the TOC as either TINs or grids, but right clicking on the objects produces differing pull down menus as explained below. Right clicking the folder offers the option to **Create new TIN** in addition to the common options shown above.



Create new TIN
This option produces a dialogue box (below) to name the TIN. On clicking OK this creates an empty object in the grids and tins folder of the Table of Contents.

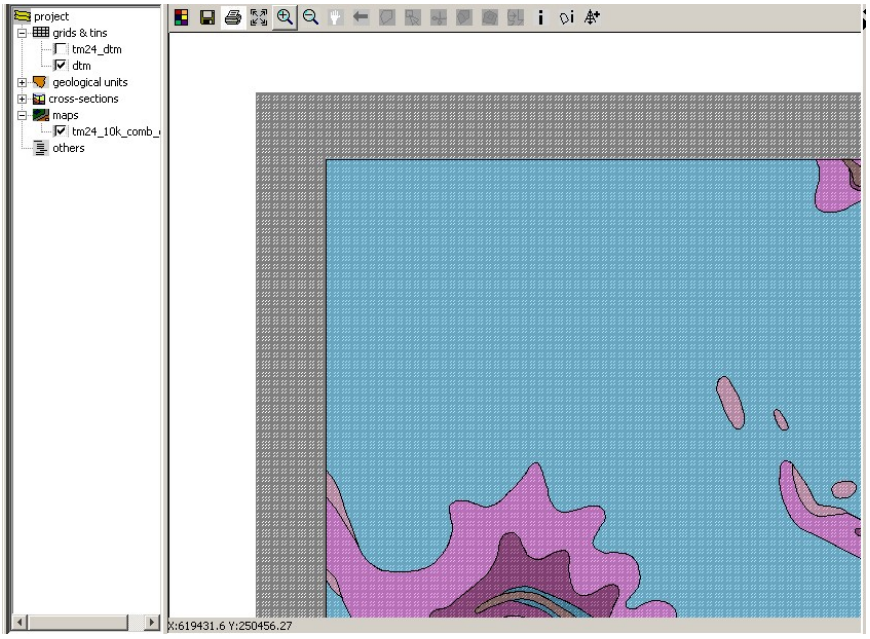


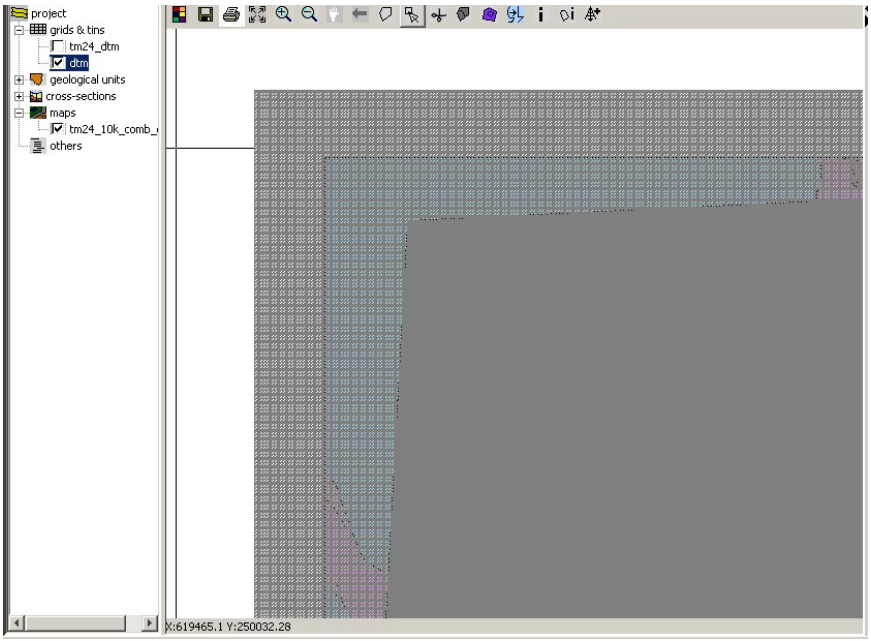
In order to then create the TIN the user right clicks on this empty object and under **extra functions** can import either an ascii grid, a GoCad TIN or scattered data points (see below). The data is then displayed in the map window as a TIN and corresponding envelope which initially equates to the full extent of the loaded dataset. For performance reasons in the default display of the triangulated surface is switched off and the envelope is set to transparent.

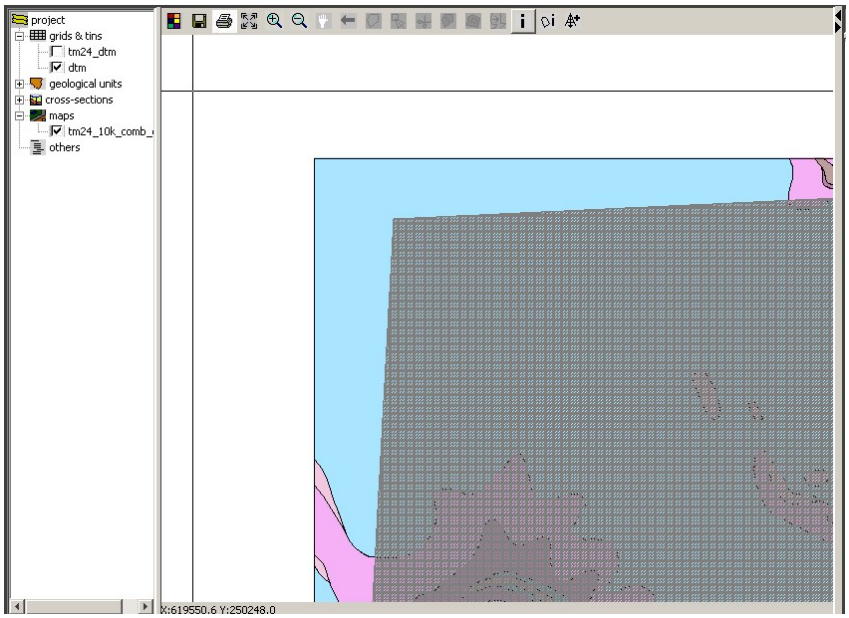


These settings can be adjusted using the property box for the individual TIN/grid (right click on object see below)

The next picture below shows the semi-transparent envelope and the triangulated surface. The envelope can be made editable, right click > **switch on edit**, and then the envelope may be revised to a bespoke area or shape for calculation, (second picture below) this can include holes and islands in the same way as the envelope for any geological unit (see below).
Once the envelope is satisfactory **switch off edit** and then select from the **extra functions** the **Trim TIN** option. The TIN is then trimmed to the extent of the envelope as in the third picture below. Alternatively the default envelope can be deleted and a new bespoke one created using the polygon construction tools.

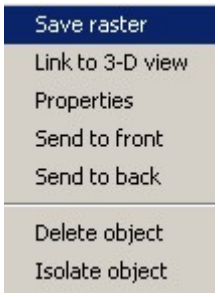






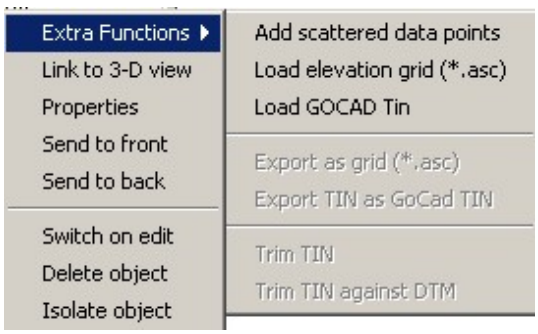
When the project is saved it is stored in the *.gsipr as the clipped Tin and envelope and so is available instantly for further calculation (provided it is the selected DTM coverage in the Workspace properties).

Right clicking on an individual grid produces the following menu:



Save raster enables saving of ascii grids as surfer grids, and vice versa
Link to 3-D View view sends an individual surface grid to the 3D viewer
Properties calls up the grid property box described in Section 3.1.1.2
Send to front self explanatory
Send to back ditto
Delete object ditto
Isolate object ditto

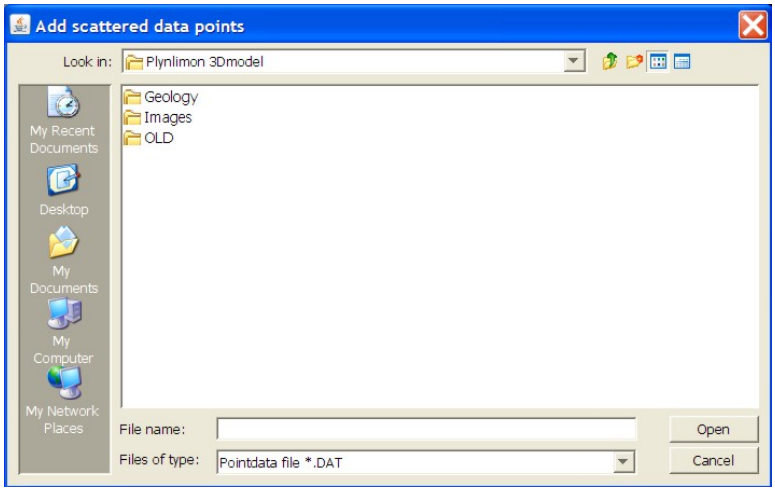
Right clicking on an individual TIN will produce this menu



NOTE: when a TIN is loaded into the object the upper loading options are greyed out, conversely when an empty object awaits loading of a TIN the lower calculation options are greyed out.

Add scattered data points

This function allows extra data points such as points along contour lines or scattered helper points where data is sparse to support the conceptualised geometry of the unit.

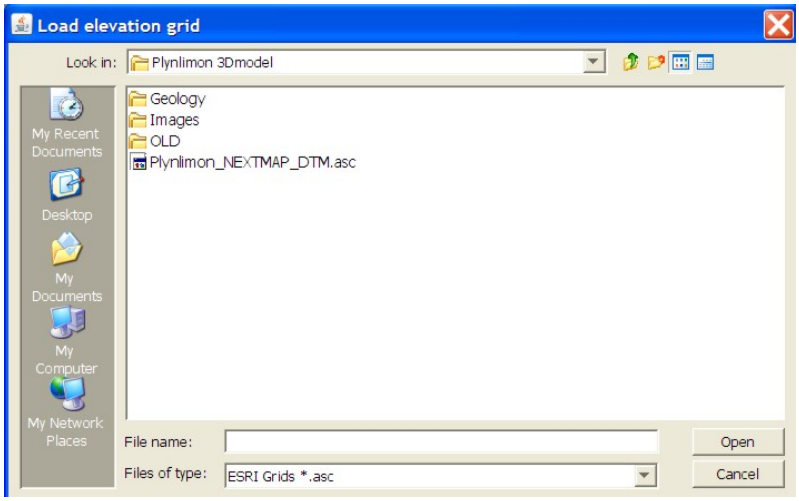


The data points are imported as tab-separated xyz ascii data in *.dat format., note this file does not contain a header which is shown below for explanation only. The unit must already contain an envelope.

Point name	X	Y	Z
A1	620227	245907	21.36207

Load elevation grid

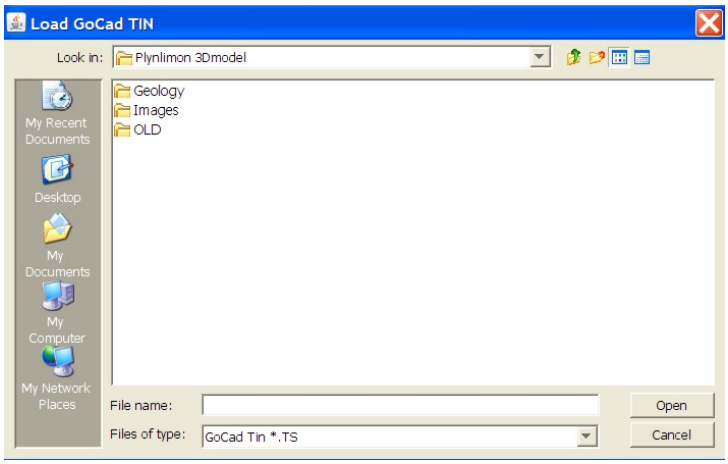
Selecting this option allows the user to import an existing ascii grid into a geological unit using the following standard loading box.



In this process the raster is automatically triangulated and so can be used in model calculation and also it can be stored and clipped as part of a model file (see Section 3.2.2 & 4.6)

Load GoCad Tin

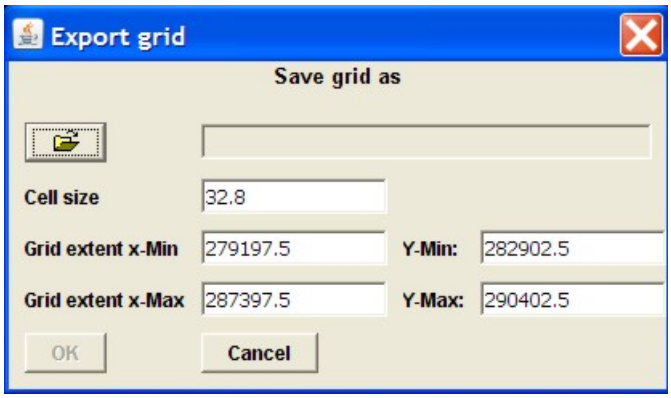
This function allows the direct import of GoCad Tsurf TINs into a GSI3D project When saving the project the imported surface(s) it will be saved as part of the model *.gxml file.



NOTE: This also allows the import of GoCad TINs for use as the DTM.

Export as grid (*.asc)

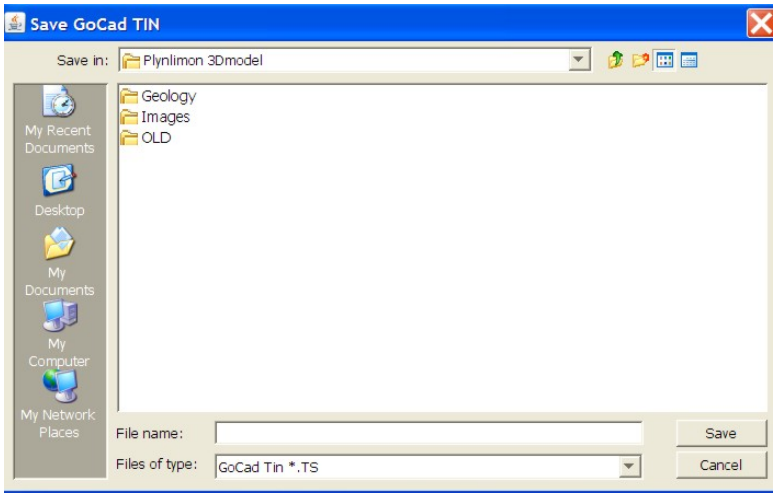
This function enables the export of the base of an individual geological unit as an ASCII grid.



This standard save box requires the user to define the cell size and extent of the grid, the default value the cell size is model dependant and the extent is the whole project area.
The following two options enable interchange of surfaces with the GoCad modelling package

Export TIN as GoCad TIN

This function will export the TIN into proprietary GoCad format. The created TIN will be an exact copy of the GSI3D TIN .



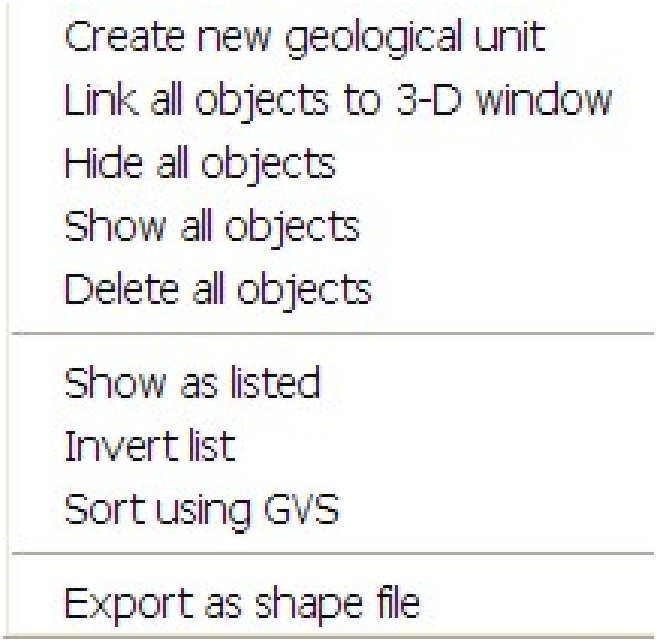
Trim TIN See description above under the **Create new TIN** option

NOTE: This is an essential tool for clipping a DTM to a required area for calculating the model. It also can be used to clip GoCad TINs and export them.

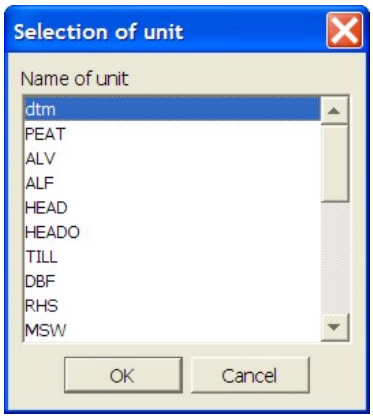
Trim TIN against DTM This function enables any TIN to be truncated (cut) by the DTM selected in the workspace.

2. Geological units

This folder contains the geological units, their envelopes/crop-lines and after calculation the triangulated top/base (volumes).
A right click on the overall geological units folder gives the following options



Create new geological unit



This option produces the list of geological units contained in the GVS. The required unit is selected and clicking OK opens an empty object with the unit name in the folder.

Show as listed

Orders the geological units in the map view to display with the youngest at the top i.e. looking down from above. This should match the geological map.

Invert list

Orders the l units in the map view to display with the oldest at the top i.e. looking from beneath.

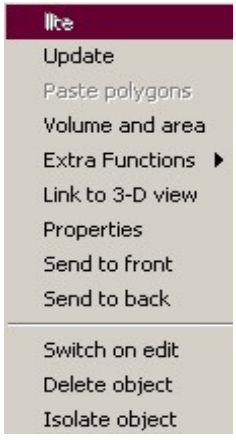
Sort using GVS

This orders the geological units in the folder into their GVS controlled correct stratigraphic order. This function is most useful when new units are inserted or units are not loaded in stratigraphic order.

Export as shape file

Exports the map window view as an attributed shape file *shp via dialogue box..

Right click on the individual geological units produces the following menu.



***Unit ID* displays the gvs code for unit**

Update

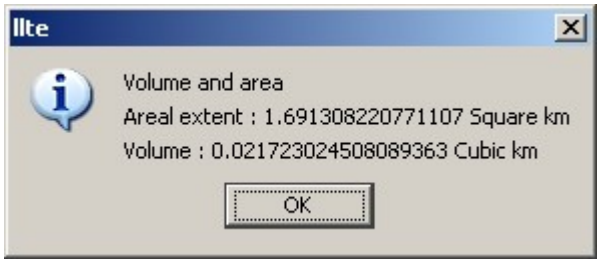
This refreshes the unit in the map window in response to changes made to the correlation lines in the section window or its envelope. It does not compute the TINs (see section below)

Paste polygons

This function pastes polygons copied from the geological shape file into the receiving editable unit .after copying from objects in the map folder (see below)

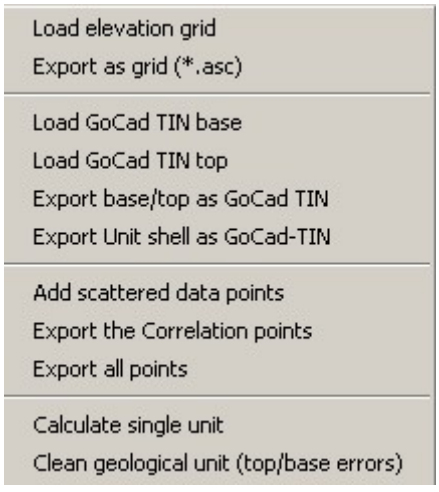
Volume and Area

After calculation of a model clicking on this option will produce the information box (below) listing the volume of the unit and its areal extent.

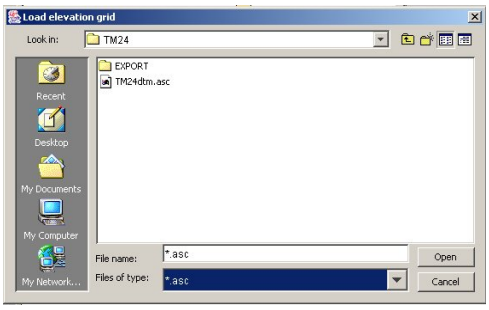


Extra Functions

This expanded pull-down menu allows the user to edit the selected unit and import-export data.


Load elevation grid
Export as grid (*.asc)
Load GoCad TIN base
Load GoCad TIN top
Export base/top as GoCad TIN
Export Unit shell as GoCad-TIN
Add scattered data points
Export the Correlation points
Export all points
Calculate single unit
Clean geological unit (top/base errors)

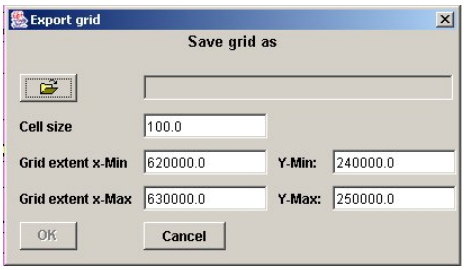
Load elevation grid selecting this option allows the user to import an existing ascii grid into a geological unit using the following standard loading box, however this will not be saved in the *.gsipr file unlike objects in the grids and tins folder.



In this process the raster is automatically triangulated and so can be used in model calculation and also it can be stored and clipped as part of a model file

NOTE: This function is described in Section 3.2.2 & 4.6, as it is the mechanism to import DTMs or other model capping surface.

Export as grid (*.asc)
This function enables the export of the base of an individual geological unit as an ASCII grid.



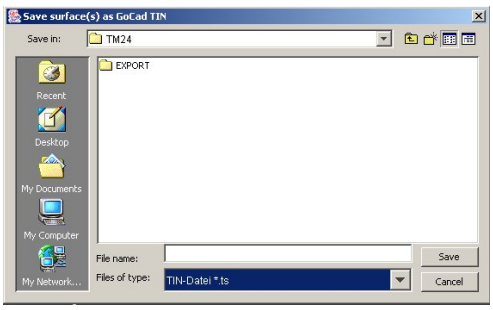
This standard save box requires the user to define the cell size and extent of the grid, the default value the cell size is model dependant and the extent is the whole project area.

Load GoCad Tin base/top

A GoCad surface can be imported from a standard dialogue to form the base of a geological unit using this function for calculation of the model, however this will not be saved in the *.gsipr file unlike objects in the grids and tins folder. Loading a top of a unit, contrary to the established GSI3D topology rules forces a capping surface for a single unit into the calculation. This is particularly useful for lensoid bodies.

Export base/top as GoCad TIN

This function will export either the base or top of an individual geological unit from the calculated model into proprietary GoCad format. The created TIN will be an exact copy of the GSI3D TIN.



Export Unit shell as GoCad-TIN

This similar function will export the entire volume of a geological unit (top plus base and sides) into a proprietary GoCad format.

Add scattered data points

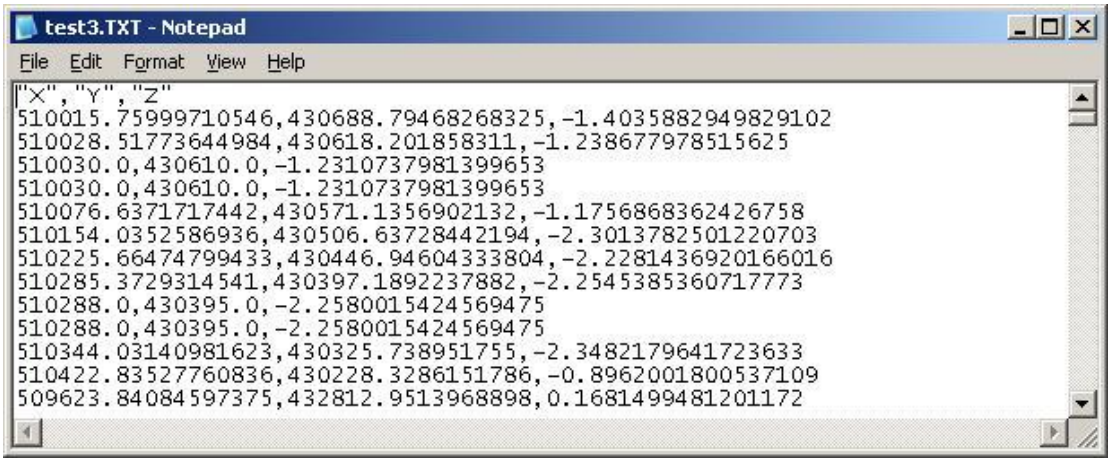
This function allows extra data points such as points along contour lines or scattered helper points where data is sparse to support the conceptualised geometry of the unit. however these data will not be saved in the *.gsipr file unlike objects in the grids and tins folder.

The data points are imported as tab-separated xyz ascii data in *.dat format, note this file does not contain a header which is shown below for explanation only. The unit must already contain an envelope.

Point name	X	Y	Z
A1	620227	245907	21.36207

Export the correlation points

This function exports all the correlation points from the sections as comma-separated x,y,z values in ascii format (see below) to a named file *.txt



Export all points

This function exports all points (envelopes and correlation nodes) as comma-separated x,y,z values in ascii format to a named file *.dat

Calculate single unit

This function enables the calculation of triangulated base of a single geological object.
NOTE: This button is useful during modelling, because it only takes a few seconds to compute the unit and it can be checked immediately.

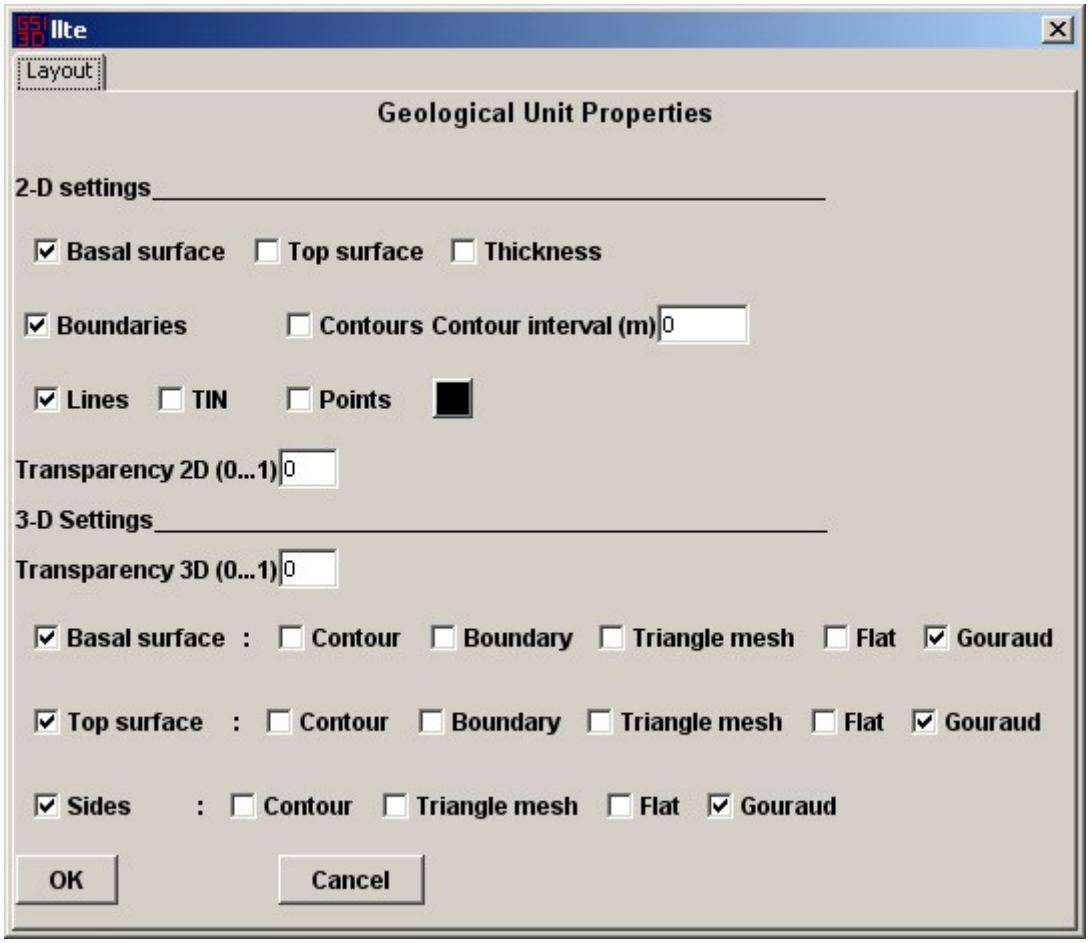
Clean geological unit (top/base errors)

This function will clean the top and base of an individual geological unit by removing any cross-overs between the two surfaces.

Returning to the right click on geological unit menu

Properties

Right clicking on this produces a window for adjusting the properties of the individual geological unit layer display (Envelopes and/or TINs) shown below



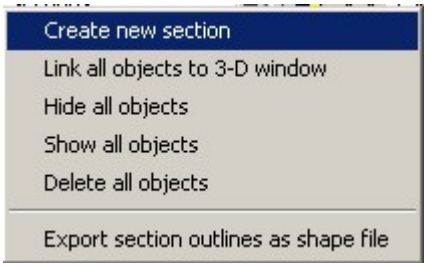
Please note that with the exception of unit boundaries, lines and points all these options refer to the calculated TINs.

The **2-D Settings** include the ability to select either (check) the **Basal surface** or the **Top Surface** or **Thickness**
Boundaries allows the user to switch on and off envelope boundaries
Contours and Contour interval enables the user to contour the selected surface
Lines, TIN, Points enables the user to select one or more options for displaying correlation lines, triangles or nodes of the selected surface
Point, Line or Tin Colour Button displays a palette to choose the colour of the unit
Transparency 2D defines the transparency of an envelope in the Map window (0 solid; 1 transparent)

The **3-D Settings** include the ability to select either (check) the **Basal surface** the **Top Surface** or **Sides** for display in the 3-D window. All can be displayed at once. The options for each display are by checking a single box from **contours, boundary, triangle mesh, flat or Gouraud.**
Transparency 3D defines the transparency of the unit in the 3D window (0 solid; 1 transparent)

3. Cross-sections

This folder lists all the cross-sections loaded from the *.gxml file that are available for viewing in the section window and whose alignments are displayed in the map window. A right click on the cross-section folder gives the option to create a new section in addition to the standard functions


Create new section
Link all objects to 3-D window
Hide all objects
Show all objects
Delete all objects
Export section outlines as shape file

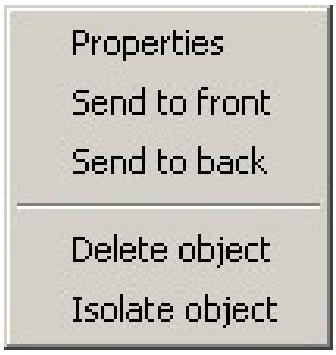
Create new section

This option enables the name of the new section to be defined, once entered click OK and then section is automatically added to the Table of Contents in the section window as the active section so that construction can begin.

Export section outlines as shape file

Uses a standard dialogue box to export the network of sections in plan view.

Right clicking on individual cross-sections brings up the standard menu.



Properties, click to open the section view properties window and adjust settings as required (described in Sections 3.3.2 and 3.3.3)
Send to front Self Explanatory
Send to back Ditto
Delete object Ditto
Isolate object Ditto

4. Maps

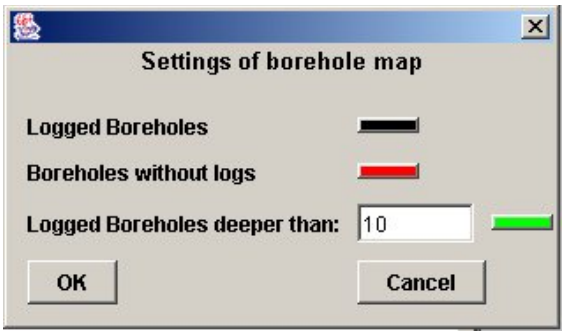
This folder lists all *.shp files and other maps loaded, which may include multiple geological map layers, bedrock, superficial, artificial, mass movement or combinations of these. Similarly thematic map .shp files may be imported such as the polygons for the IMAU reports. Also displayed in this folder are topo maps and map layers showing the distribution of boreholes within the study area derived from the downloaded SOBI tables.
A right click on the folder gives four standard options

NOTE: Only Voronoy maps can be sent to the 3D window using this menu

Right clicking on individual objects gives menus dependant on the type of object, here the non standard options are explained

Borehole maps

Right clicking on a borehole distribution map produces the settings box below



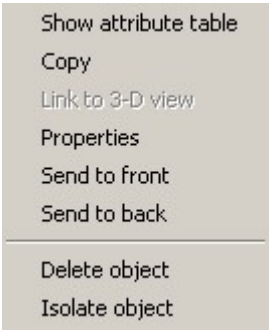
The user can choose colours for boreholes with and without downhole logs, and also define a third colour for boreholes exceeding a user-specified depth.

Horizontal Slice maps

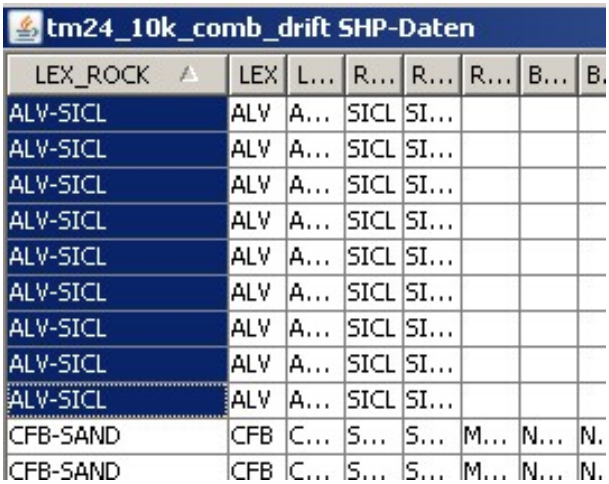
Right clicking on these maps gives the option to export the slice as a *.shp file, under ***Properties*** the polygon outlines can be switched on or off with a check box and the transparency adjusted.

Shapefiles

Shapefiles can be used to aid construction of individual unit distributions (envelopes), right clicking on the loaded file gives the following standard options plus options



Show attribute table shows this supporting data table in a separate window, (below right) tables can be sorted alphanumerically by geological unit or any other parameter by clicking on the header item. Once the table is clicked on and activated only highlighted polygons are then displayed in the map window (below left). Standard keystrokes using Ctrl and Shift can be used to make selections.



Copy

The selected polygons of the editable unit can then be copied from the sorted table) to the clipboard using this function. They can then be pasted (see above) into the recipient geological unit in the geological units folder (right click on unit and select **paste polygons**).

Properties

Select this option to display the standard shapefile dialogue box described above in the loading instructions at Section 3.1.1.2

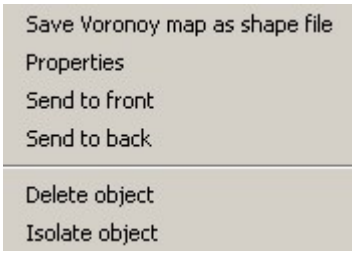
Raster Maps

Right clicking on an individual raster map enables the selection of **Properties** which brings up the standard raster map property box (see above at Section 3.1.1.2).

Voronoy Maps

Right click on a Voronoy Map produces an additional options:

***Save Voronoy map as shape file*:** self explanatory dialogue box



Properties

Selecting this option brings up the property box described above at Section 3.1.1.2

Numerical Parameter Data

After creating a numerical parameter object described in 3.1.1.2 these data appear in the map folder as an object with the parameter name. The name is displayed with an extension, stating if the plot has a relative *(r)* elevation to the DTM or an absolute *(a)* elevation Right click on these objects gives the standard options plus ***Save Voronoy map as shape file*** and an ***update*** function.

5. Others

At present this folder is not used.

3.2.3 'mouse click'

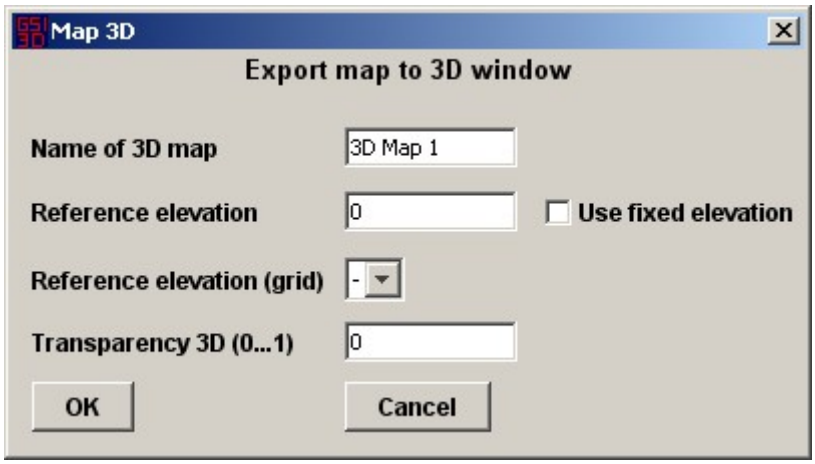
Use the left mouse click to query objects such as boreholes, DiGMapGB polygons, section lines , contours and grid displayed in the map window. The query information is displayed at the bottom left corner of the map window.

NOTE: Every mouse click leaves behind a small red triangle that indicates the location of the query.

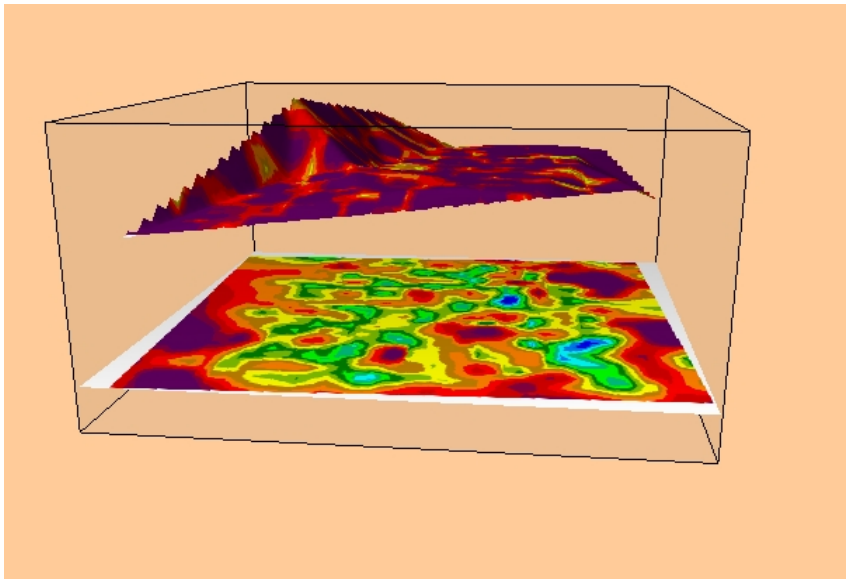
Right click anywhere within the map window produces the following menu

Send map view to 3D window

This function enables the map view to be displayed in the 3D window as a frozen image. The dialogue box Map 3D gives the option to either attach the map as a flat 'carpet' at a user specified fixed elevation (box must be checked) or attach it to an existing grid from within the workspace.

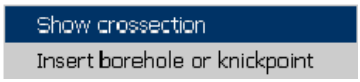


According to these settings the image (below as an example 2 geophysical slices) appear either in relation to the topography given by the DTM or any other surface (see below, upper slice) or as a plain horizontal slice in the defined absolute elevation (see below, lower slice).



NOTE: when a map with a very large areal extent is used as a drape the pixilation in 3D maybe unsatisfactory.

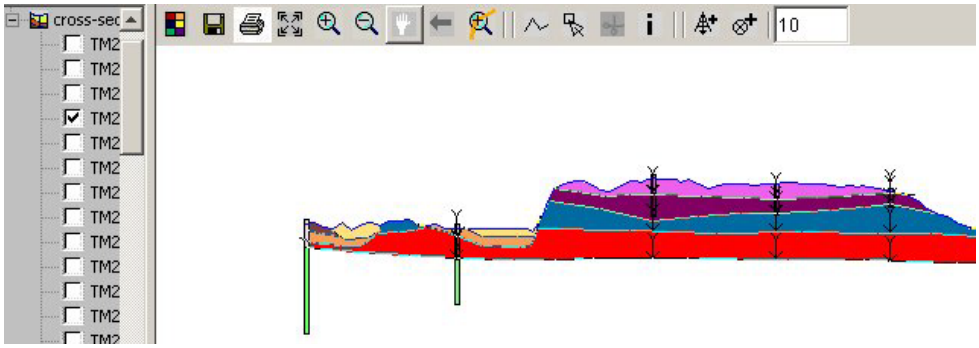
Right click with selected info tool on an active section or any envelope edge gives the additional options below:



Show cross-section
Right click on a section line gives the option to displays this section in the section window.

Insert borehole or knickpoint
Right clicking on any part of a section selected in the cross-section window shown in red in the map window gives the option to insert a previously selected borehole (make it the active log in the borehole viewer) or any new point chosen previously with the red triangle.

3.3 The section window



3.3.1 Toolbar

The toolbar contains the following icons from left to right

1. Select background colour
Click brings up a standard palette to select background colour

2. Save section window as image

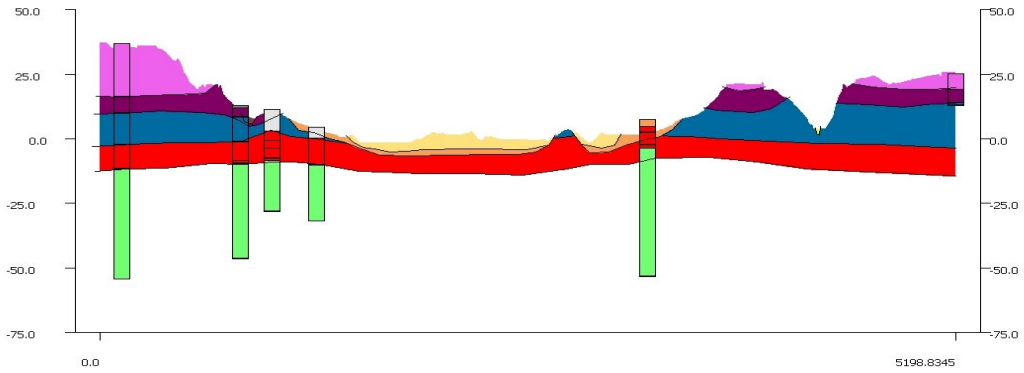
To export a synthetic or a hand correlated section as*.jpegs or *.tifs right click in the 2D window and select ***save section as image***. It works in the same way as the function in the section window, apart from the fact that NO geo-registration file will be produced.

Only The active section will be saved. In the dialogue box that appears select the resolution of the image in metres per pixel (m/pixel) to set the scale required for printing. The table below show the required values to export the images at different scales for a typical print resolution of 300 pixels per inch (ppi).

SCALE	M/PIXEL
1:50000	4.23
1:25000	2.12
1:15000	1.27
1:10000	0.85

GSI3D will automatically generate a vertical scale along the x axis and will display the length of the section along the y-axis. In Paint Shop Pro or CorelDraw or similar graphics software, set the image resolution to 300ppi and ensure that the original width of the image does not change. Only one section can be exported at a time.

NOTE: File extensions must be entered in the File name dialogue box.



Exported jpeg from section window with scale bars

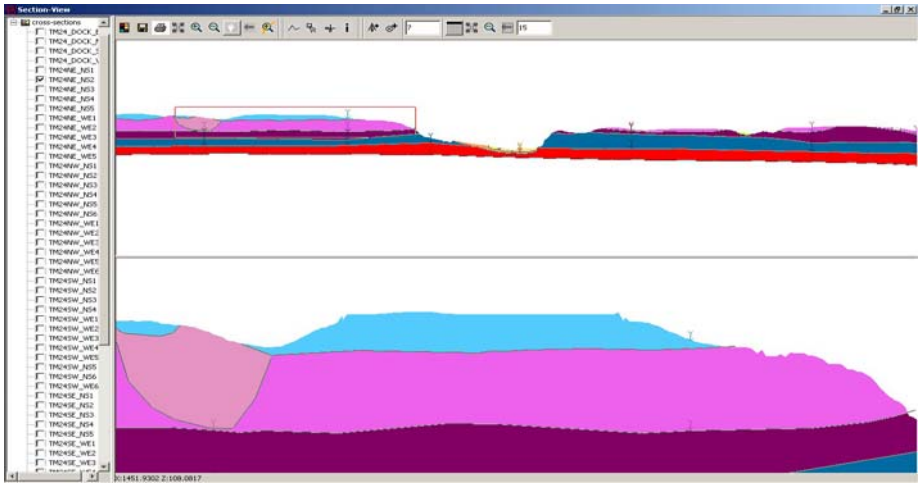
TIP: Occasionally, where a high vertical exaggeration has been set on the 2D sections, the m/pixel resolution may result in part of the section being lost. A lower resolution can be set, to capture the entire section but the scale will be affected. In these cases, the section length at the required scale should be calculated and set after exporting from GSI3D into CorelDraw or Paint Shop Pro

3. Print Map Window
Click on this icon to print the map window to a printer
4. Zoom to full extent
Click, fits the whole object to the dimensions of the section window
5. Zoom In
Click on, then click in window and hold down whilst dragging mouse to construct marquee around area to zoom in to, release on completion
6. Zoom Out
Click on, click in window, and repeat to incrementally reduce the magnification
7. PAN
Click, then click in window and hold, drag to new position and release, drag and drop.

8. Back to previous view
Click, displays previous view, not an undo button though
9. Fit section view to view in map window. This function enables the user to zoom in the map window to exactly the same segment of a section that is currently displayed in the map window.
10. Draw line
Click on the icon to activate
Click where you wish to place the first node then drag and click to add additional nodes finishing the line with a double click.
11. Edit line
Click on the icon to activate
Click on the line you wish to edit, the nodes are displayed
Edit the nodes as follows
To reposition, click and hold, drag and release at new position, drag and drop.
To insert click on the line where a new node is required
To delete double click on the node you wish to delete
NOTE: the last 2 nodes of a correlation line cannot be deleted. Use right click to delete line!
12.Split line
Select this tool and place a node (single click) above the line to be cut and then extend to a second node below the line (double click), The cutting line disappears and the cut line remains as two still attributed segments.
13. Info tool
Click to activate, then position cross hair on the object or location you wish to interrogate, the x and z coordinates automatically scroll in the footer bar.
For right 'mouse click' options see Section 3.3.3.
14. Add borehole to section
For use in adding boreholes whilst constructing sections, with the borehole selected in the map window using the Info tool (and displayed in the borehole viewer to validate its worth) simply click on the icon to add the borehole to the section under construction.
15. Add point to section
For use in adding knick points whilst constructing sections, with the location selected in the map window using the Info tool simply click on the icon to add the location to the section under construction.
16. Set vertical exaggeration
This input field enables the setting of vertical exaggeration, after typing the desired value, hit enter to make the change occur.

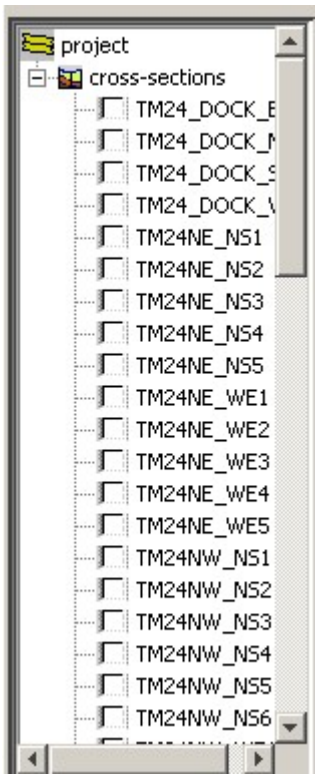
TIP: In work on Quaternary sequences in several parts of Britain a value of about 15 has proved useful although the presence of any very deep boreholes means that those sections then becomes very large (deep) requiring careful navigation using the PAN and ZOOM options.

17. Dual View
This button splits the section window into an upper and lower pane. When clicked the icon changes form and four additional familiar icons then appear to the right governing the properties of the lower pane (see below). Clicking again on the dual view icon reverts to a single pane. In split pane mode the displayed area of each pane is shown as a red lined box in the other pane. In the example below detailed correlation can be performed in the lower pane whilst the overview is displayed in the upper pane.



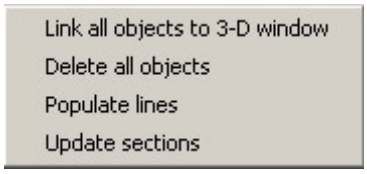
Example in dual view mode

3.3.2 Table of Contents



Double click on the Project icon to expand the cross-sections folder containing the sections loaded from the *.gxml file into the section window. Only one section can be shown (by ticking box) at once.

Right click on the cross-section folder gives a menu as follows

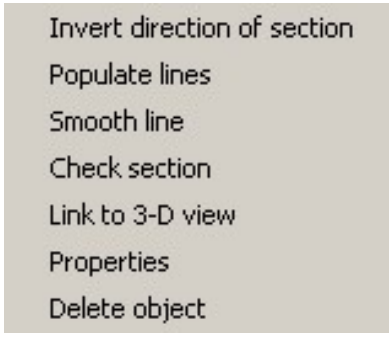


Link all objects to 3-D window Click this option to load all the sections into the 3D window.
Delete all objects: self explanatory

Populate lines: this function displays an entry screen to type in the maximum distance in metres between two adjacent nodes that is permitted along correlation lines, where this distance is exceeded an equally spaced node(s) are inserted to populate the line. **This function updates all lines in all loaded sections (see also below)**

Update sections: self explanatory

With the cross-section folder opened **right clicking on the individual sections** gives

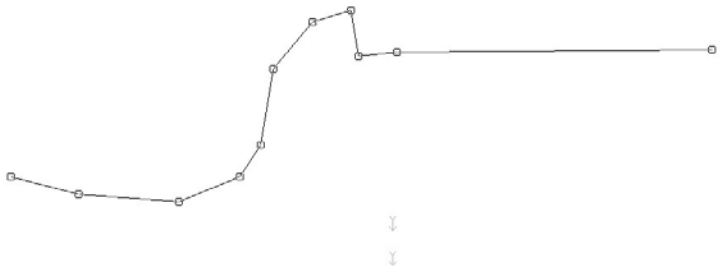


Invert direction of section
Reverses the section in the display and will be saved in this changed orientation unless switched back.

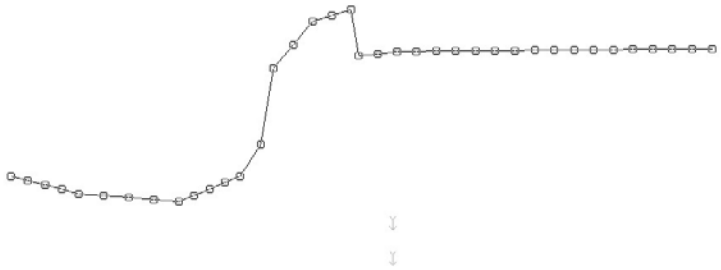
TIP As additional points can only be added to the end (right end) of a section in the window you can invert a section to add points beyond the start point of a previously digitized section.

Populate lines: this function displays an entry screen to type in the maximum distance (in the x dimension) in metres between two adjacent nodes that is permitted along correlation lines, where this distance is exceeded an equally spaced node(s) are inserted to populate the line. **This function updates all lines in the selected section only.**

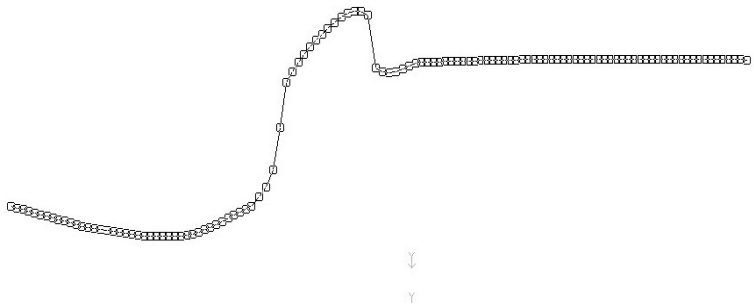
Smooth lines: *this function displays an entry screen to type in the distance in metres (in the x dimension) between two adjacent nodes that is permitted along correlation lines, this function however not only populates the line but changes the shape of the line to a smoother shape.* ***This function updates all lines in the selected section only.***



Line before population or smoothing



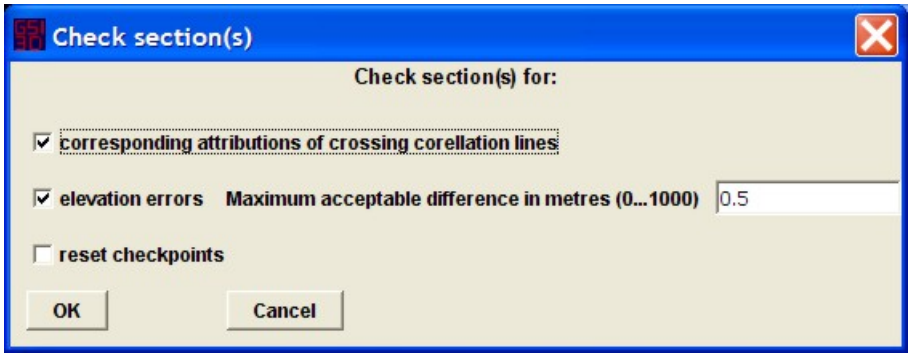
Line populated (nodes every x metres in x dimension), line shape remains



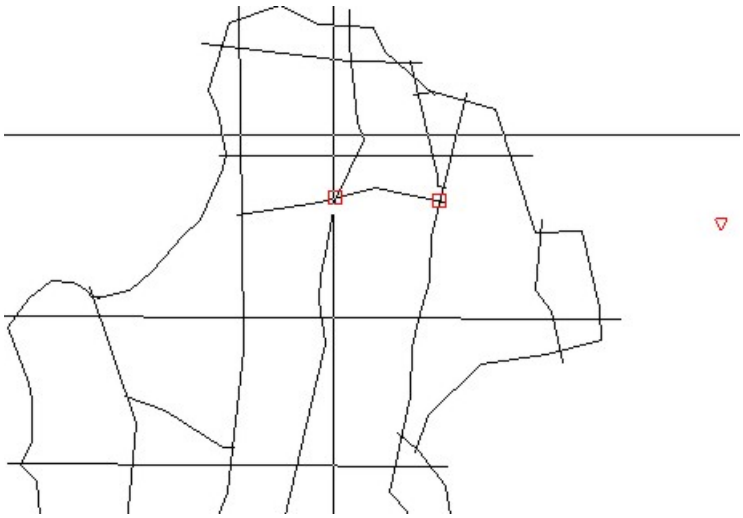
Line smoothed (nodes every y metres in x dimension) line shape smoother

Check section(s)

This option produces the section checking dialogue box (below)



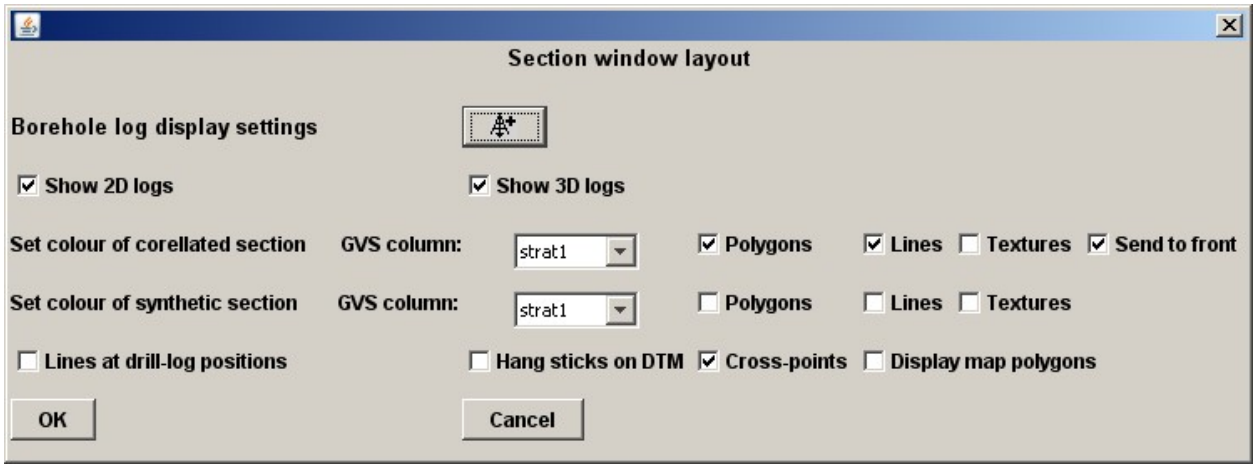
Errors are reported in the map window with red squares covering the intersections as shown in the example below



Properties

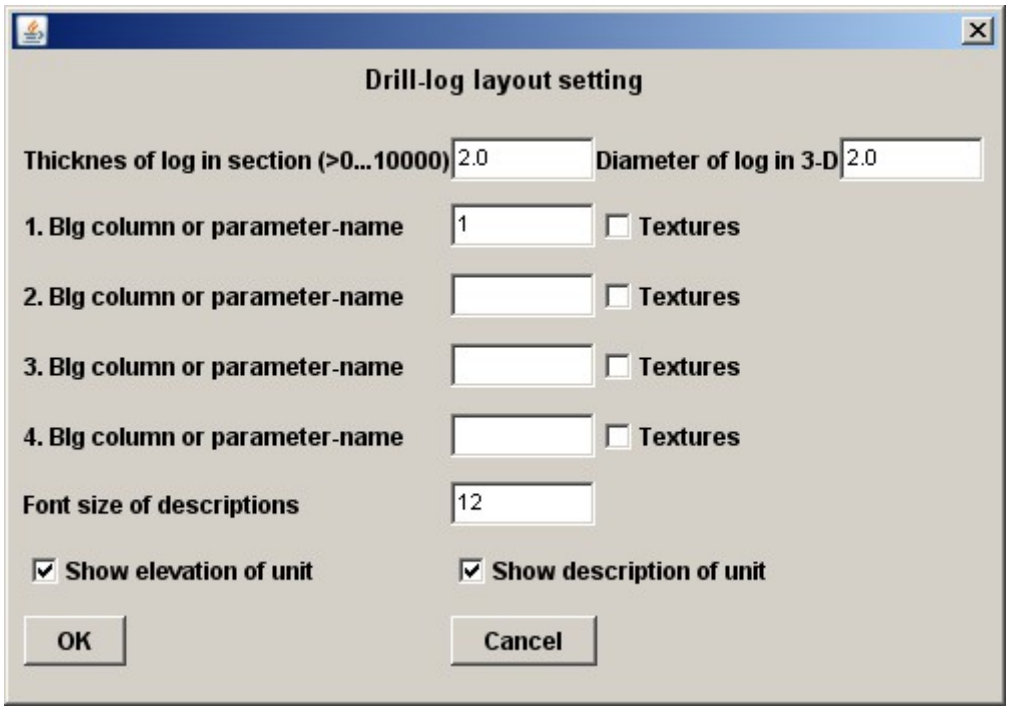
Properties when set apply to all selected sections then displayed in the section window

Click on *Properties* to reach the Section layout window



The borehole log display settings button at the top

sets the display for sections and boreholes and brings up the Drill-log layout setting window below:



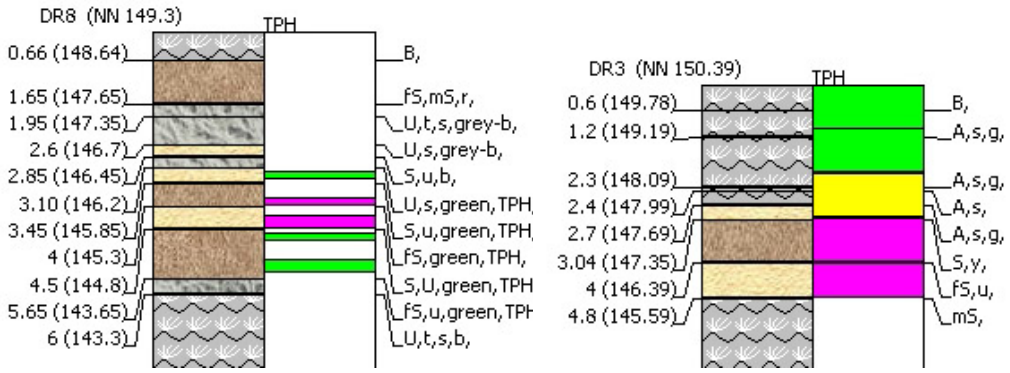
Thickness of log in section sets the thickness of the borehole stick in the section window the default is 100, for modelling at 10K-25K tile size with sections up to about 10km long a stick thickness of about 20 is suitable.

Diameter of log in 3-D sets the thickness of borehole sticks in the 3D window, % is a sensible choice for most scales of investigation, and the default is 100.

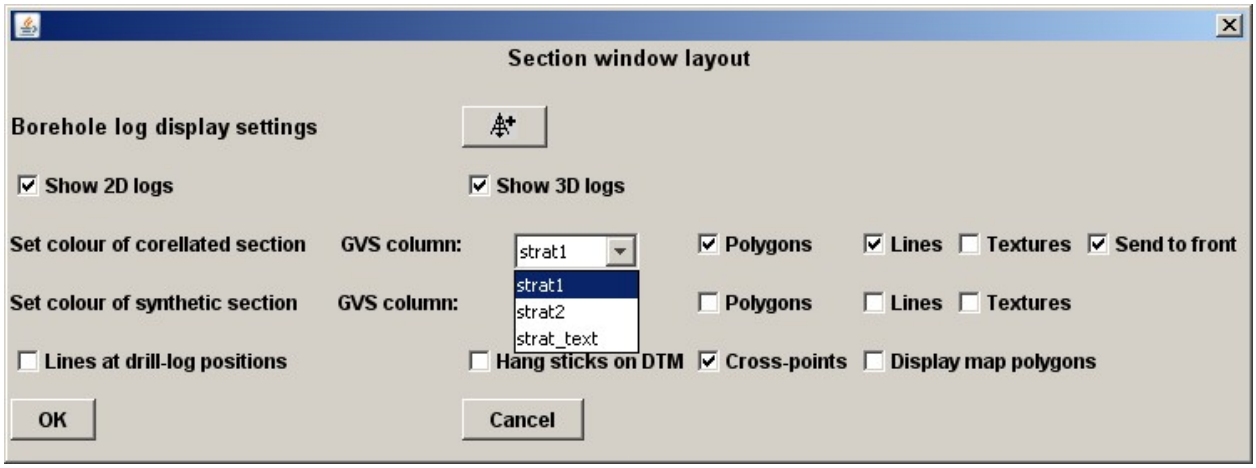
Up to 4 borehole sticks can be displayed, each showing properties selected either from the columns (0,1,2 3… from left to right) in the downhole *.blg file or parameters from a point data source, here the header value has to be entered (SPT in this example).
Tick the *Textures* box alongside each field to display representative textures instead of colours, as stored in the TEXTURES folder (see Section 2.1.8)

The user can change the appearance of the text on section windows in the font size input field.

It is possible to switch on and off the labelling for the borehole sticks. *Show the elevation of unit* displays OD and reduced levels of the units and *show description of unit* annotates the borehole sticks with their codes from the downhole *.blg file.



Multiple column display of borehole logs including chemical data



Elsewhere in the section window layout above:
Tick *Show 2D logs* for boreholes to be displayed in the sections.
Tick *Show 3D logs* for boreholes to be displayed in the 3D window.

Set colour of correlated section and *Set colour of synthetic section* set the colour of the correlated or generated sections. Select here the *GVS column* from the pull down menu giving the option to colour the section by different the various gvs attributes. (see Section 2.1.7).

By ticking *Polygons* or *Lines* the user can decide to look at either just the lines or the panels of the section. Ticking *Textures* will utilise the texture as specified in the Legend file.

Send to front ticking this box gives the option to send the correlated section or parts of a section to the front overprinting any synthetic section panels, this can be used when producing composite synthetic and correlated sections

TIP: (for checking a model it is useful to just display model (calculated) and correlation lines. This way any discrepancy between correlation line (black) and modelled line (blue) is very obvious.

Lines at drill-log positions
In areas of crowded borehole data for ease of visualisation the borehole sticks and knick points can be displayed as vertical lines by ticking this function.

If *Hang sticks on DTM* is ticked the borehole start heights are adjusted to the DTM. The accuracy of borehole levelling is likely to be more accurate than most current DTMs. Also boreholes logs may not always start from ground level. e.g. motorway routes now cut and filled, gravel workings etc.

The *cross-points* of correlation lines are shown using the symbol below this feature can also be switched on or off.

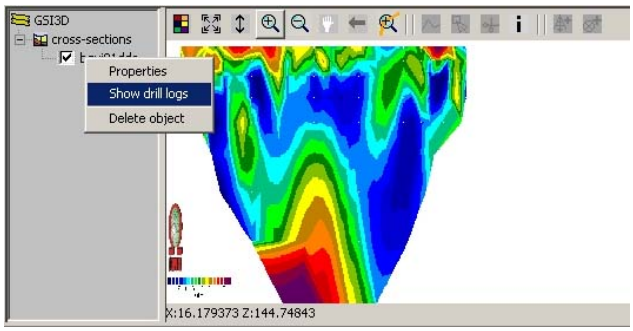
Display outcrop-band ticking this option enables a coloured band of predetermined thickness showing the geological units at outcrop along the DTM trace. (see Section 3.1.1.2)

TIP: Section construction is often hindered by cluttered annotations. Depending on the quality of data coloured up borehole sticks may be sufficient to enable good correlation lines to be constructed and labelling can be switched off most of the time.

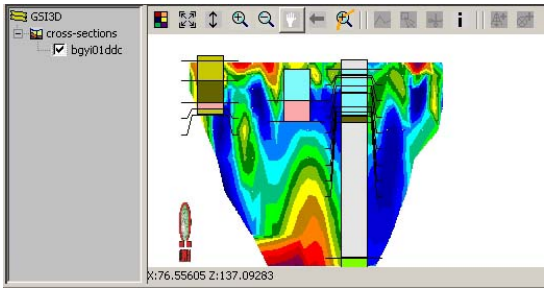
Raster images

If the cross-section constitutes a raster (*.jpg) (see Section 2.1.6) right clicking on the item produces the option to show boreholes within a certain buffer.

the opening dialogue box choose the *Show drill logs* button, which opens the *Distance of drill-logs* dialogue box. Type in the appropriate maximum distance of the drill-logs to be displayed in relation to the section



Click *OK* and the boreholes in the created buffer appear mapped on the vertical raster map.

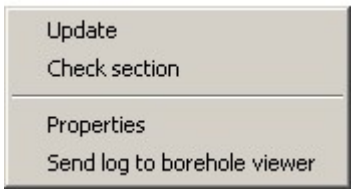


TIP: With the *Geo-register vertical geophysical section* button from the *Tools* pull down menu (see Section 3.1.1.3) any sectional picture can be integrated into GSI3D, ranging from quarry pictures to hand-drawn cross-sections.

NOTE: Remember if a section is deleted from the table of contents in this way and then a new version of the *.gxml file is saved the deleted section will not exist in the new)*.gxml file.

3.3.3 'mouse click'

Use the left mouse click to query objects such as lines, boreholes, correlation lines, cross-points and outcrop ticks. The query information is displayed at the bottom left corner of the section window. Right click anywhere within the section window produces the following menu



Update refreshes the section window. Any changes to correlation lines will only become effective when this button is pressed.

TIP: When loading sections into the 3D window without having edited or updated the section all faces will appear grey and may need refreshing via the update button

Using the ***Check Section*** function the user can check the active section using the map checker function described in Section 3.3.2

Properties this option is described above at Section 3 3.2

Enable logs to borehole viewer

This option when selected from the dialogue enables boreholes, click yes.

Once activated using the Info tool selected in the icon bar a right mouse click on a borehole sends it to the borehole viewer window. Disable by selecting dialogue box again and clicking no.

Clicking on objects in the section window gives the following additional options:

For correlation lines

Left click on a correlation line displays its attribution in the footer bar.
With the Info tool selected right click gives

Change line name Right click and type in the GVS code for the unit that the line forms the **base** of.
Delete line Click and confirm choice
Populate line inserts nodes as described above to line only
Smooth line inserts nodes as described above to line only

For boreholes

Left click on stick, the borehole number and units in the stick are given in the footer bar of the window
Right click on borehole or knickpoint gives the extra option to delete it plus the other standard options described above

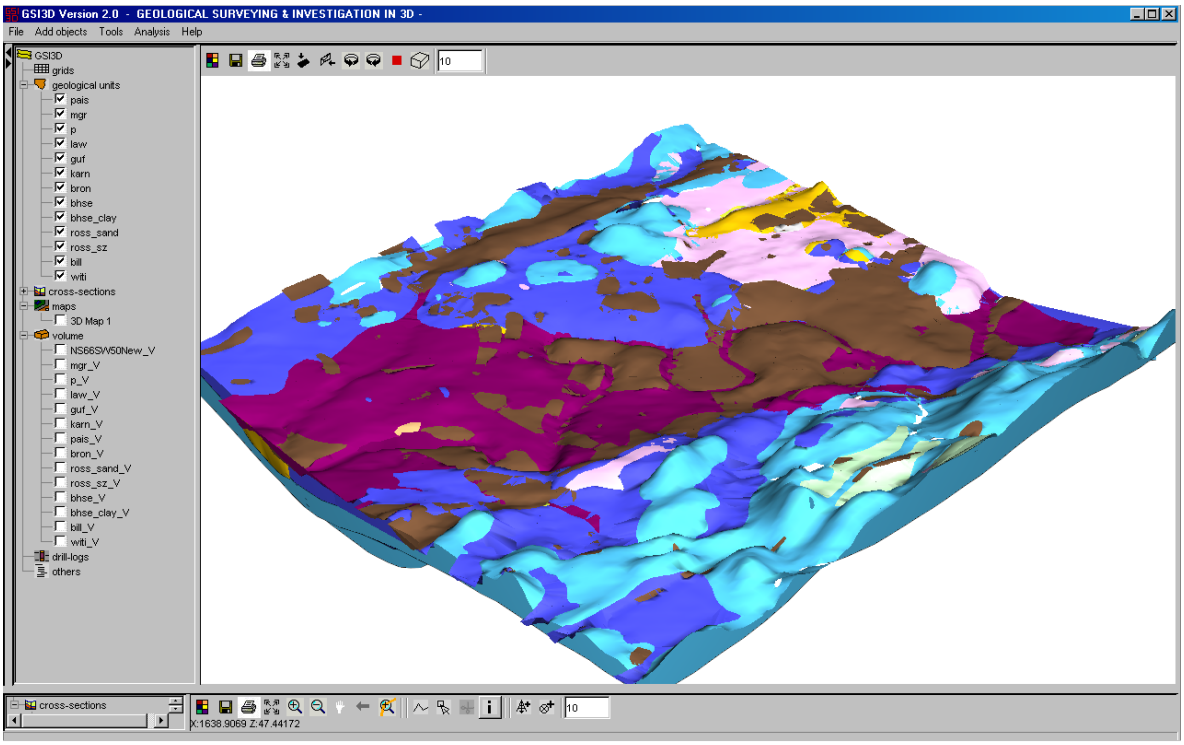
NOTE: When a section is zoomed out very far, it is often hard or impossible to right click on boreholes or drill log lines.

For cross-points

Left click on the arrows the name of the intersecting cross section and the unit whose base is indicated by the arrow are displayed in the footer bar
Right clicking gives the option to *show crossing section* i.e. switch to the intersecting section the point queried is then highlighted on the intersecting section with a red cross.

3.4 The 3D window

An example 3-D window showing Quaternary deposits in Glasgow



- Navigating the 3-D window is carried out using mouse control.

- Holding the left mouse button down and moving the mouse around rotates the model in all directions
- Holding the right mouse button down and moving the mouse up and down zooms in and out of the model.
- Holding down both mouse buttons (or the middle mouse button, depending on mouse model) and moving the mouse around pans the model in all directions

3.4.1 Toolbar

The toolbar contains the following icons from left to right

1. Print Map Window

Click on this icon to print the map window to a printer

2. Zoom to full extent

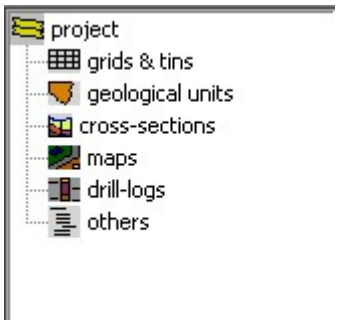
Click, fits the whole object (fence diagram, surface, envelope, grid 'model') to the dimensions of the 3D window

3. Plan view

Adjusts the 3D view to a vertical view, i.e. the model is viewed from above in plan view.

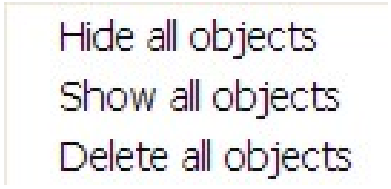
4. Side View
This instantly adjusts the model to a side horizontal view.
5. Rotate right
Click, starts the model spinning incrementally to the right, anticlockwise about a vertical axis preserving any tilt (inclination) present at the start. Once spinning the icon changes to a stop sign that when clicked halts the spin
6. Rotate left
Click, starts the model spinning incrementally to the left, clockwise about a vertical axis preserving any tilt (inclination) present at the start. Once spinning the icon changes to a stop sign that when clicked halts the spin**. NOTE: rotation speed will depend on model size!**
7. Render on/off
Toggle button that switches off the 3D window to save memory and back on again.
8. Set vertical exaggeration
This input field enables the setting of vertical exaggeration, after typing the desired value, hit enter to make the change occur.

3.4.2 Table of Contents

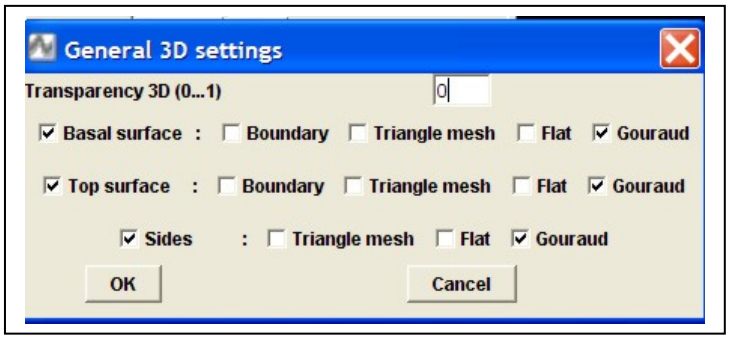


Folders for the various types of layer information are the same as in the map window (see Section 3.2.2). In addition and special to the 3D view window is the folder for drill logs (shown above) imported from the borehole viewer (see Section 3.5)

Double click on the project icon to view the folders in the 3D window, these can be expanded by double clicking and individual objects switched on and off using standard tick boxes and reordered by right clicking to activate the layer and then selecting the send to front or back options as shown below
Right clicking on any of the folders gives the standard options as follows



In addition the Geological units folder gives the option to set the properties of all the units as **General 3-D Settings** (see a similar dialogue for the individual geological units in Section 3.2.2) and **Sort using GVS** to order the units in the TOC as in the GVS. This results in the folder collapsing and it needs to be expanded once again



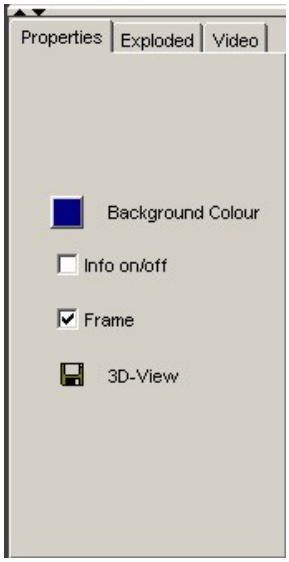
NOTE: Deleting objects from the 3-D view does not delete them from the other windows.

NOTE: Properties of Geological units are individually set in a combined 2-3D settings box described above in Section. 3.2.2.

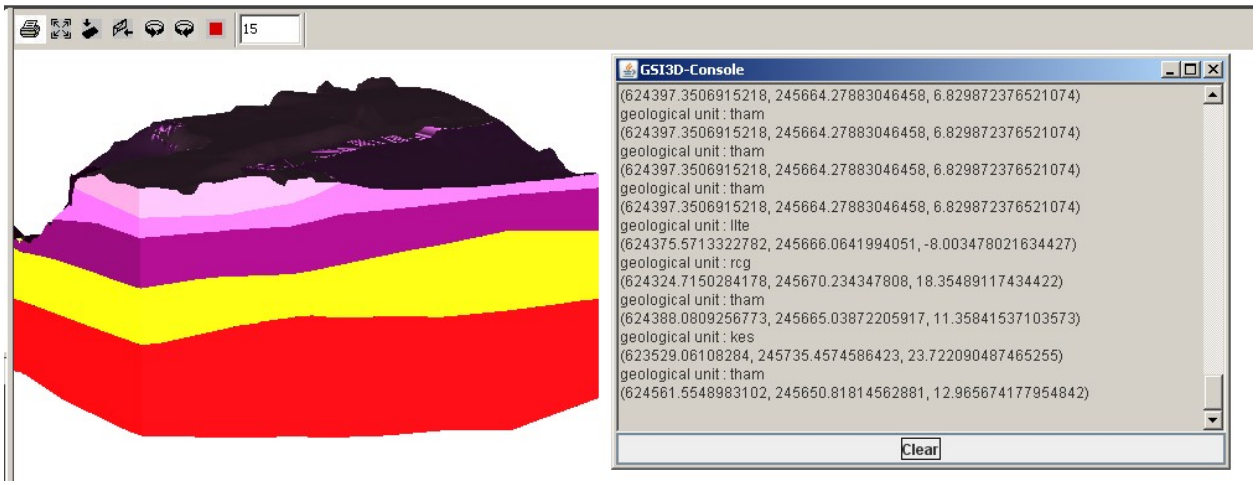
Right clicking on individual objects within folders produces the following menu
Again the properties dialogues are embedded within those described for the map and section windows, the other options are self-explanatory.

The Table of Contents border also contains a screen which can be expanded or minimised using arrows as for the main windows. This screen contains three selectable tabs at its header Properties (default), Exploded and Video (shown below).

Properties



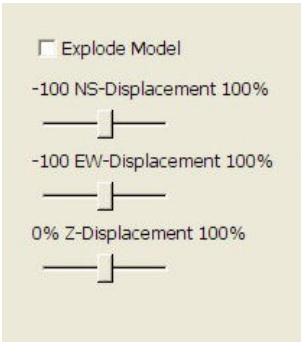
Clicking on the **Background Colour** button brings up the standard palette to select the colour. With the **Info** box checked a left mouse click in the 3D window will produce the query results in the Java console which needs to be first activated from the Windows pull down menu see Section 3.1.1.5. The selected objects is displayed in yellow as shown below



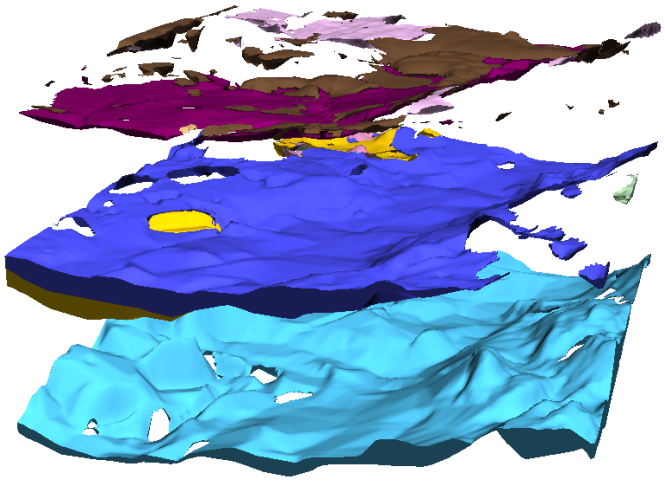
The example above also shows the box frame around the model that can be switched on or off using the **Frame** box. The **3D-View** icon enables saving of the 3D window as an image where the user is asked to enter the image width in pixels up to a maximum of 1280.

NOTE: Printing of screens in GSI3D is often best done however by maximising the window and using a screen capturing software package

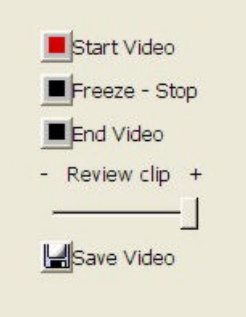
Exploded



Checking the **Explode Model** box separates all the geological units in the model according to the GVS order with the topmost units displayed highest (see below). Use the slider bars to change the exploded view in the x, y and z dimensions.

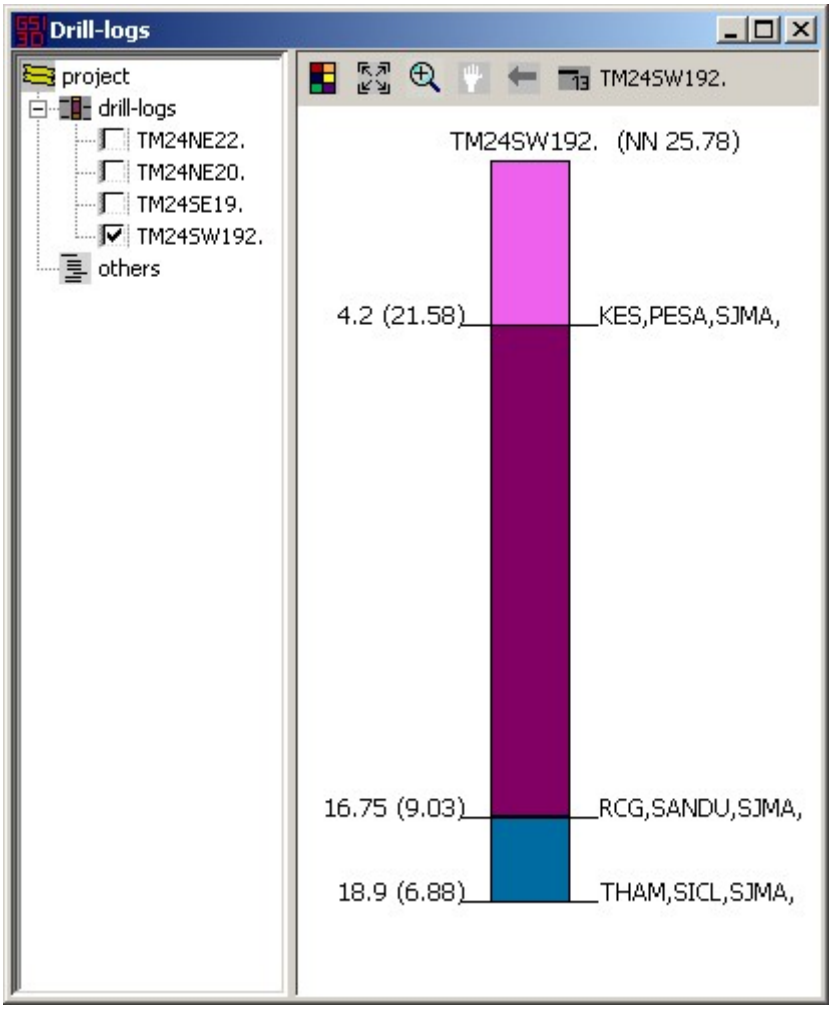


Video



The buttons in the Video tab are self-explanatory, the **Save Video** option produces a dialogue box to name the file and select its type and folder destination.

3.5 The Borehole Viewer



A typical borehole viewer screen is shown above, it is activated from the Main Screen tools drop down menu and requires rescaling.

3.5.1 Toolbar

1 2 3 4 5 6 7

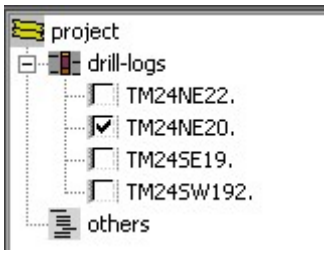
The toolbar contains the following icons from left to right

1. Select background colour
Click brings up a standard palette to select background colour
2. Zoom to full extent
Click, fits the whole object (annotated log) to the dimensions of the section window
3. Zoom In
Click on, then click in window and hold down whilst dragging mouse to construct marquee around area to zoom in to, release on completion
4. Pan
Click, then click in window and hold, drag to new position and release, drag and drop.
5. Back to previous view
Click, displays previous view, not an undo button though!
6. Export coordinates of unit depth
This function enables the ad hoc writing of x,y,z coordinates from a particular borehole into an export file
7. Borehole ID display, lists the displayed borehole number

3.5.2 Table of Contents

Double click on the GSI3D icon to expand the Table of Contents (TOC)

The drill-logs folder contains a list of selected boreholes in sequence, these can be ticked on and off with only one visible in the window at any one time.



Right clicking on the list of boreholes or a single borehole gives the option to send all listed logs to the 3D window.

NOTE: when a borehole is first passed from the main window to the single borehole viewer, the scale and view area need to be readjusted. This involves "panning and zooming in" to the top left of the window to expand the scale of information.

3.5.3 'mouse click',

Right click anywhere within the borehole window gives the option to set the properties of the borehole sticks. The *Drill-log layout setting* dialogue box is the same as the one used for the section window and is explained in detail there (Section 3.3.2).

4. Working in GSI3D - methodology and best practice

GSI3D Version 2.6 is the final methodology and software tool for the modelling of shallow subsurface geology in superficial and simple bedrock terrain.
The following chapter describes in detail, how to build sections, envelopes and how to complete the model using examples from Southern East Anglia.

4.1 Scales and Types of Investigation

Any geological project has its' own aims and objectives. For example in the systematic surveying of terrain procedures and outputs are pre-determined and the sizes and scales of outputs are consistent. However many surveying or modelling projects are commissioned by a client with very specific needs.

Additionally the availability of geological data, such as DEMs, geological linework, boreholes, and geochemical sample points is never evenly distributed. For example a 1:10.000 scale geological map sheet in an urban area may have thousands of registered borehole records and site investigation reports whereas a similar size area in a Welsh National Park might contain no boreholes whatsoever.
It is thus apparent that models produced with GSI3D will vary in scale, detail and resolution.

Three basic categories of investigation are suggested here (see table below) based on current BGS experience> these are summarised in the table below, but in reality even these are part of a continuum from the most general assessment of the geology down to a very detailed investigation on the scale perhaps of a quarry for planning extraction and reserve estimation or the site investigation for a major engineering structure.

4.2 Borehole coding

All BGS held borehole data should be examined. Coding must be consistent with the BGS stratigraphical and lithological lexicons available on the intranet. Only boreholes with reliable information that contribute to the understanding of the sediment body geometry or model should be coded. For example where multiple closely spaced boreholes show the same sequence only the deepest or best-described logs have been coded. The datasets should be edited (cleaned) to remove erroneous grid references and correct or supply start heights. Boreholes whose logs are without recorded start heights can be estimated from the 1:10K topographical sheets or the DTM.

The choice of boreholes should be largely independent of any pre-conceived geological model. Whilst the project remit may require that boreholes offering a certain type of information are included, care should be taken to ensure that an objective approach is used when including or excluding primary data.

The borehole stratigraphical classification held in Borehole Geology tables can be revised as an iterative process during the development of the sections and the geological model. The level of stratigraphical refinement of the coding is largely driven by the recognized geological mapping units at surface and the aimed resolution of the model. Coding of distinct lithologies within members and formations is also recommended to permit subsequent analysis of facies patterns. Complex glacial sequences present special problems as stratigraphical principles often break down. When working in areas with poorly understood stratigraphy the coding of just lithological descriptions is recommended rather than trying to interpret the unknown.

NOTE: Please note the difference between geological interpretation (stratigraphy) and codification of borehole descriptions (e.g. lithology, colour etc.).

NOTE: Collective Best Practice Guidelines for borehole coding have been published on the BGS Intranet.

Type of Survey or Investigation	Overview	Systematic	Detailed – Site specific
Section Spacing	several km	0.5-1.5 km	< 500 m
Section Length	Tens of kms	5-10 kms	<5 km
Density of Coded Boreholes	Less than 1 per square kilometre	Commonly 5 - 20 per square kilometre	Often hundreds per square kilometre
Mapping Level	Major Groups and Formations only	Formations and Members, big lenses	Members and thin individual beds and lenses, Artificial Ground
Modelling speed (excluding data preparation**)**	Up to hundreds of square kilometres a day	2-10 square kilometres a day	< 2 square kilometres a day
Scale	Compatible with 1: 250K and 50K geological linework	Compatible with 1:25K and 1:10K geological linework	Compatible with detailed site plans at scales of 1-5:1000
Modelling Output	Often just sections and an open fence diagram.	Computation of surfaces for export to GIS.	Computation of surfaces and lenses for export to GIS.
Uses	Useful for education, visualisation and overviews (e.g. catchment characterisation), first-pass assessments	Builds a 3-D model stack for interrogation in site selection, route planning, resource assessment, recharge and aquifer studies etc.	Detailed 3-D model for analysis of thickness, volumes, flow paths providing bed-by-bed stratigraphy for use in Urban planning and site development.
Minimum Unit thickness	2 metres	1 metres	0.1 metres

Summary table of the various types of investigation and their characteristics.

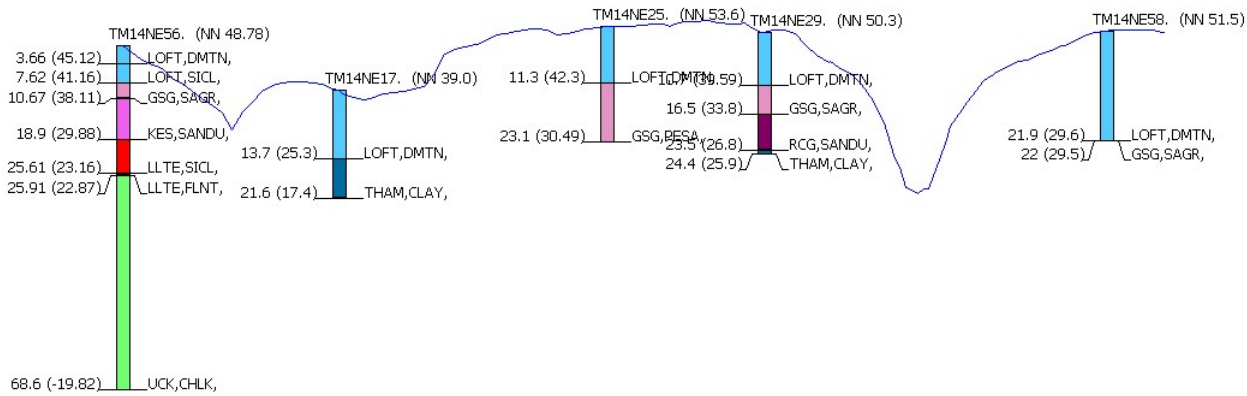
4.3 Building sections - construction and correlation

Construction and Correlation

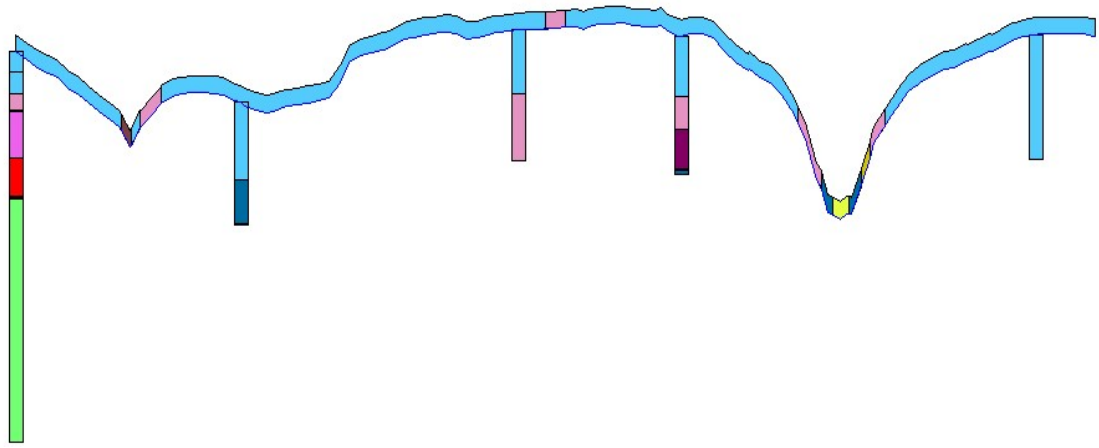
Section construction and correlation follows the following steps

1. Set up a project workspace*.gsipr with the following data assembled, dtm, gvs, gleg and borehole bid-blg files. Load geological linework as *shp files (these are not stored or linked to the workspace at present)
2. Minimise the 3D window and open the Borehole Viewer window and drag to a suitable position (top right works well with the 3D minimized).
3. Select *Create new section* from the *Tools* menu and give it an appropriate sequential name e.g. TM14_NS1 (it is recommended to adopt a naming convention that includes the quarter sheet or project name) in the dialogue box. This name will automatically appear ticked (editable) in the table of contents of the section window.
4. Looking at the borehole distribution, the surface topography and expected subsurface structure in the map window decide a rough alignment for your section and begin to use the *Info* tool to examine the logs of boreholes close to the start of the intended line of section. You may need to zoom in and out whilst doing this. Use the *zoom to full extent* tool to refresh if needed. Also bear in mind that sections do not need to run from borehole to borehole and can even be assembled without boreholes using the insert knickpoint function.
5. Start your section either by selecting a borehole or if none is suitable selecting a start point displayed as a red triangle in the map window using the *Info* tool.
6. Click on either the *add borehole* or *add point* icon (whichever refers) on the section window toolbar.
7. Pan along your intended line of section and select your next borehole or point along it, then continue to add points, and/or boreholes until the section is complete.
   NOTE: as the section line is constructed it is highlighted as active (red) and grows across the map window. Sometimes you need to hit Update (on right click) or Zoom to full extent in the section window to refresh
8. Use the *zoom to full extent* tool in the section window to examine the string of coloured boreholes sticks and points plus the trace of the DTM produced (see A below) check it looks OK, adjust properties by right clicking in the window and selecting properties and vertical exaggeration by clicking on the icon and typing in an appropriate value (try 15 for starters). It is often best to tick off the annotation text in the borehole dialogue properties box to focus clearly on the geology. (text shown in A1 below).
9. Tick the *Display map polygons* box in the section window *property dialogue box* to show a coloured layer of the relevant geological map along the DTM (see A2 below) make sure your geological map was attached to the dtm on loading if not right click on the geological map object and adjust the properties.
   NOTE: It is possible to display multiple map bands across the DTM but a surface geology map (often combined superficial and bedrock) should ideally be used as this is the geology at the DTM surface.

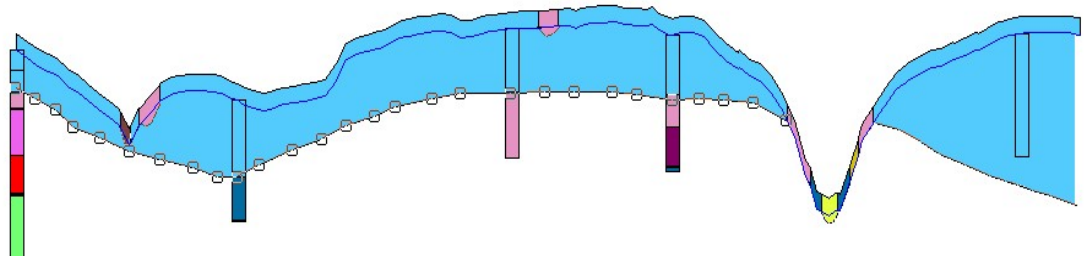
10. Then consider the geological contacts along the section in the map window and the coloured borehole sticks in the section window. This process can be helped by locking together the scales of the map and section windows (see Section 3.3.1). Start to draw lines using the *Draw line* tool in the section window on the base of shallow drift units (see B below) such as till, head, alluvium and river terraces. These are shallow dish shaped bases often running from one edge of the deposit at surface to the other. Use the *Zoom in* where needed and produce precise lines with regularly spaced nodes giving geologically sensible shapes to the units. Start with the youngest and work down the sequence (like exhuming progressively older palaeo-surfaces, erosional contacts and unconformities).
11. When each individual correlation lines is complete label it using the *Info* tool in the section window toolbar and right clicking on the line; select the *Change line name* option and type into the dialogue box the gvs code for the unit whose base it is e.g. alv for alluvium, rtdu for river terraces undifferentiated etc. The unit above the base should colour instantly via the legend file as far up as the overlying unit base or the DTM whichever comes first. Any errors in colouring up indicate vertical stacking of units that do not agree with the stratigraphy (gvs) file
12. Proceed to work down the section drawing lower and lower bases some of which at depth are likely to extend uninterrupted across the whole section. Check all units colour up correctly as you go (see C and D below). Note some of the unit extents shown here are not supported by evidence from the actual section but rely on other adjacent data. Where the section cuts already existing sections the colour-coded elevation of unit bases is displayed as arrows (ticks) in the section and can guide the construction of correlation lines (see E below). These ticks are activated by checking the Cross-points box in the Properties box.
13. When you are happy with the section select *Save project as* from the *File* pull down menu and label the file e.g.TM14v1.gsipr. This saves your first section in case of a crash as you continue to work.
14. Select *Create new section,* label it as e.g.TM14_NS2 etc then construct another section and save the project again as e.g. TM14v2.gsipr.
15. Continue to populate the area with regularly spaced sections in two rectilinear directions. Save your work frequently and keep all the sections you have drawn loaded in the section window table of contents.
16. At the start of your second and subsequent sessions of section drawing load the saved workspace with all the existing sections.



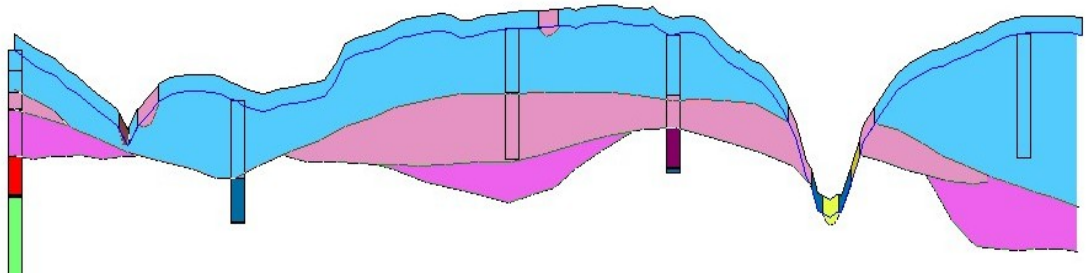
A1: DTM, borehole sticks coloured and annotation included



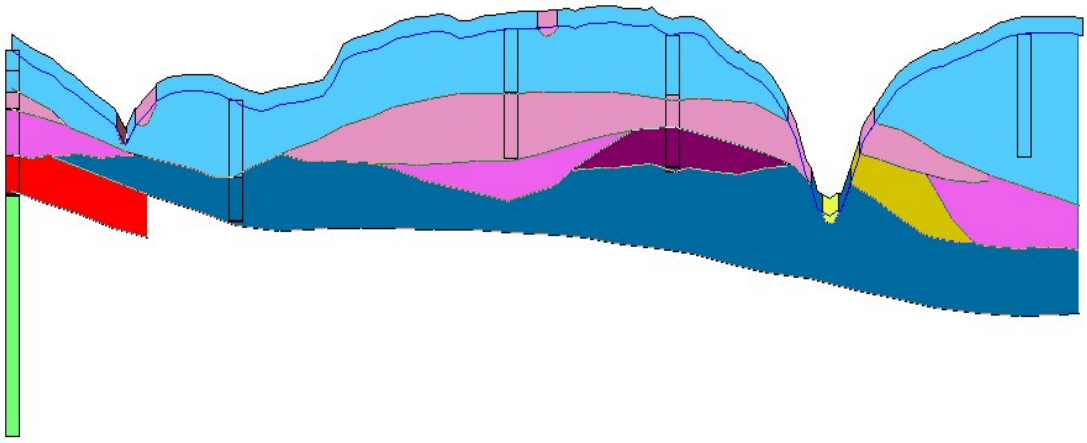
A2: DTM, borehole sticks coloured and outcrop-band coloured with annotation removed



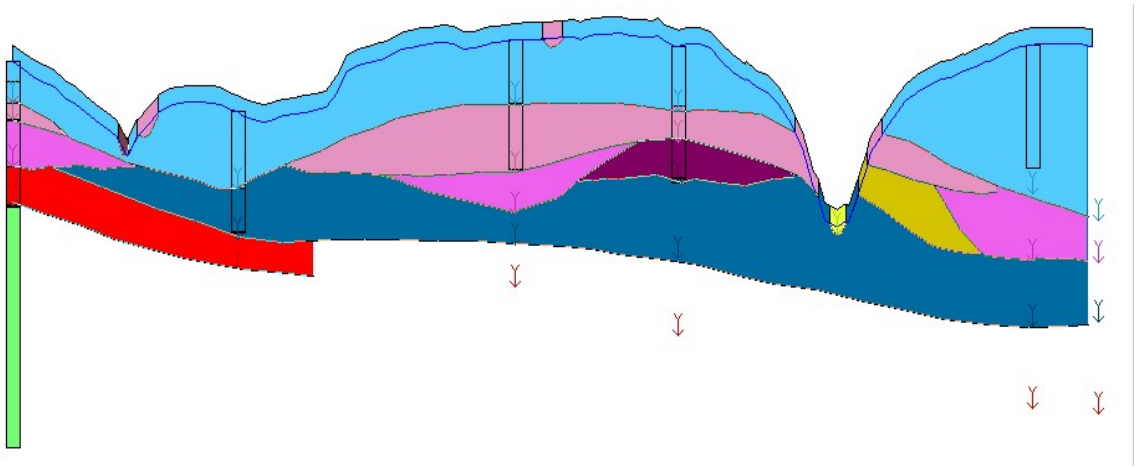
B: Correlation of superficial deposits to base of till (blue) showing node string



C: All superficial geological units correlated



D: Most bedrock units correlated



E: Levels of basal unit (LLTE) guided by colour-coded cross-ticks from intersecting sections

In southern East Anglia the 1:25 000 size tile has been adopted for systematic stratigraphical model building as the initial work with 1:10 000 tiles showed that this was too small as a workable unit for systematic section building and file handling. The geological linework used should wherever possible be DiGMapGB 10k linework, and if not available use DiGMapGB 50K. In areas with higher data density (York and Glasgow) a 10K tiling was chosen instead.

Where possible major sections should aim to intersect structures and valleys close to right angles and the North–South and West-East sections should intersect at angles approaching 90 degrees, but take account of surface topography and sub-surface structure. Smaller ancillary "helper" sections can fill in between the major sections to illustrate local variations and anomalies and incorporate linear bodies not well intersected by the major cross sections. In working with 25K tiles a line spacing of about 1km has proved acceptable in southern East Anglia and 0.5 km Manchester in studies of Quaternary, Neogene and Palaeogene deposits producing 20-40, standard 8-10km long sections per 25K sheet.

NOTE: If you want to add a borehole to the start (the left hand side in the section window) of the section simply reverse it (right click on the section in the table of contents of the section window) add the borehole and reverse it back to its' original direction.

4.4 Fitting together and checking sections

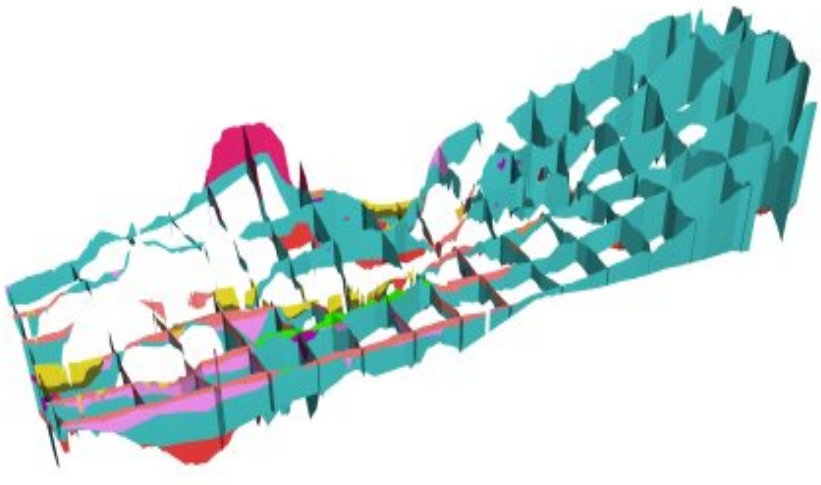
Usually two rectilinear sets of intersecting parallel sections (just for example say N-S and W-E aligned) are constructed through the area being modelled to produce a representative fence diagram of the area. As the two series are broadly normal to each other one should be aligned to cut any overall geological structure or outcrop pattern at a high angle with the other set running parallel to the structure. There will be many intersections between the individual lines of section. GSI3D displays these intersections by positioning arrows corresponding to the bases of units in the intersecting sections so that the two sets of sections can be drawn to correspond at their mutual intersection point. Swapping between sections of differing orientation produces an internal consistency within the sections. It is recommended to draw several master sections in each of the 2 principal alignments at an early stage in model building. Then with this overall master framework locked together intervening sections can be inserted to produce the desired density of fence diagram required for model calculation.

When reviewing and editing sections ensure that nodes are regularly spaced along unit bases and the shapes of these lines are geologically sensible. Magnifying the section ensures that nodes are placed accurately at the end of lines to correspond with the geological mapping displayed as a colour band along the dtm (as shown in the example above at Section 4.3). The line population and smoothing functions can also be deployed to help clean-up correlation lines whilst the Dual View mode for the Section window may also be useful when working with thin near-surface and thicker deeper units in single sections.

Additional checking of the correct fit of sections is provided for individual sections on right click – *check section* (see Section 3.3.3) and for the whole model under the *Tools* pull down menu – *check all sections* (see Section 3.1.1.3)

NOTE: To produce a model that is well tied together it is recommended when drawing surfaces guided by intersecting sections to place a node precisely on the correlation arrow from the intersecting section

4.5 Displaying fence diagrams



Fence diagram, Manchester

Finally send all the sections into the 3D window by right clicking on the sections folder in the table of contents and selecting *Link all objects to 3-D window.* Rotating and tilting to check for any anomalies in the overall fit of the sections can then help validate the fence diagram. Any anomalies should then be checked against the supporting data and interpretation to ensure they are true geological effects rather than errors in model building.

4.6 Creating the DTM (or other surface) as the Model Cap

A surface is required to cap any GSI3D model, in many cases this will be the ground surface DTM). This surface needs to be loaded into the project grids and tins folder in the following way.

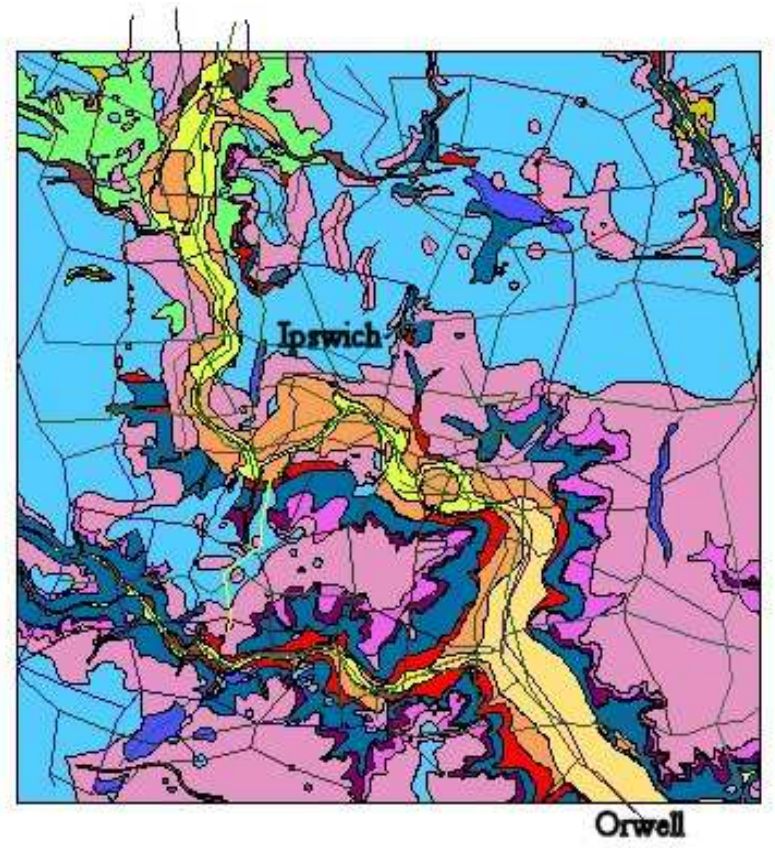
1. Right click on the grids & tins folder in the map window Table of Contents or select create new TIN under the tolls pull-down menu on the top header bar.
2. When prompted enter a recognisable name and this will then be displayed as an empty object in the grids & tins folder.
3. To load data into the object right click on the object and under Extra Functions select any of the top 3 loading options depending on the data source.
4. The loaded surface may then be trimmed to a bespoke project area for calculation as described in detail in Section 3.2.2.
5. The surface is saved in the *.gsipr file after saving the project.

4.7 Drawing Envelopes

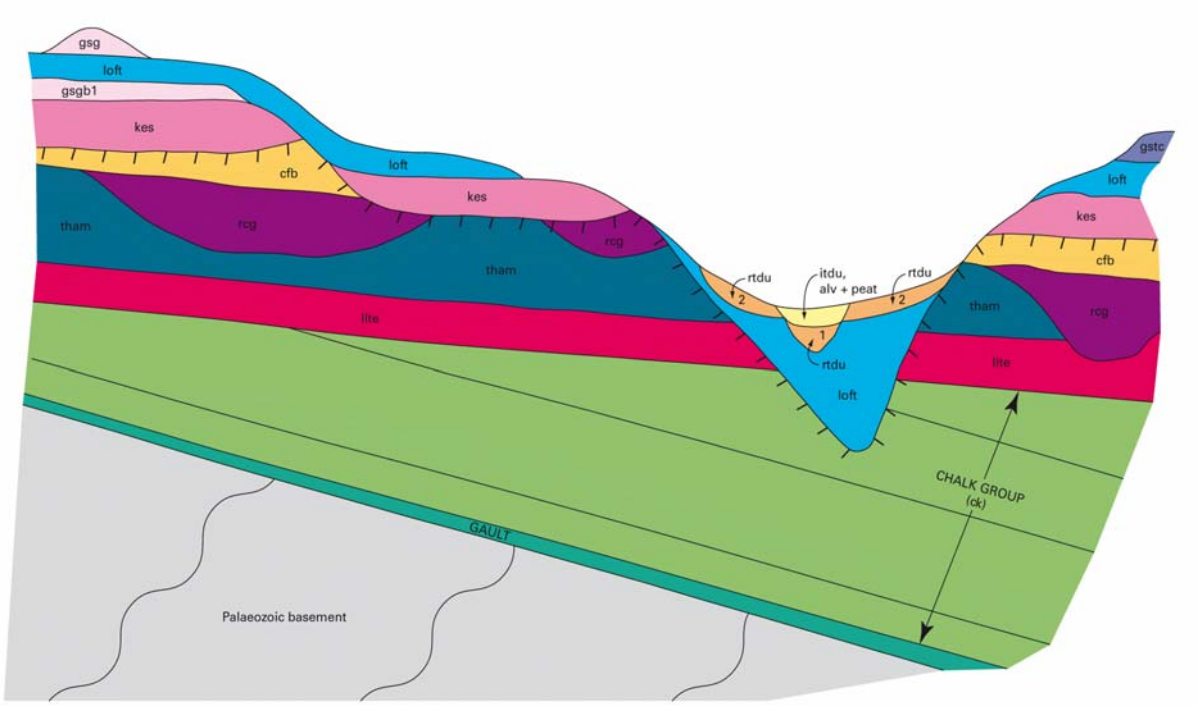
An envelope is a distribution map of any given geological unit in the sequence (GVS) showing where that unit is present (either at surface or beneath other units). In most cases the distribution is a combination of both i.e. outcrop and subcrop but in certain cases the entire distribution may be at crop (a very young surficial layer like alluvium) or entirely a buried (a deep bedrock unit for example). The envelopes are constructed in the map window, and saved into the same project *.gsipr file as the sections.

There is often no unique or correct way to construct an envelope but some general guidance is provided here. In order to do this let us examine the case of 1:25 000 sheet TM14 around Ipswich in southern East Anglia. Prior to envelope construction load all data into the map window.

Let us consider drawing 6 envelopes for this area the alluvium and river terrace deposits envelopes can be largely drawn from the surface geological linework, the Kesgrave Sands and Gravels requires a combination of surface outcrop information and data from sections and boreholes on its concealed limits, the Red Crag envelope is drawn simply from the bedrock geological linework which was produced from the sections and the Lower London Tertiaries envelope involves combining the stack of bedrock units above the chalk. The Glacial Channel Deposits envelope is drawn from the correlations along the sections only as it is completely buried. Together these examples illustrate the use of the various envelope drawing tool functions and also the variety of styles of envelopes that occur.



Geological map of TM14 Ipswich (10 x 10 km) showing superficial and bedrock geology and lines of section



Schematic section through the TM14 Ipswich area showing the relationship of units and codes used in the GVS, see below.

Superficial

	Peat	peat
	Alluvium	alv
	Intertidal Deposits	itdu
	River Terrace Deposits	rtdu
	Glacial Silt and Clay	gstc
	Glacial Sand and Gravel	gsg
	Lowestoft Till	loft
	Glacial Sand and Gravel	gsgb1
	Kesgrave Sand and Gravel	kes

Bedrock

	Chillesford Sand	cfb
	Red Crag	rcg
	Thames Group (London Clay)	tham
	Lower London Tertiaries	llte
	Chalk	ck

Colurs, names and GVS codes for TM14

A. Alluvium Envelope

Being the youngest deposit the alluvium envelope is simply constructed by from its surface distribution as it cannot be overlain (buried) by other deposits..

1 Using the tools pull down menu select create geological unit as choose the required unit, here alluvium for the list of codes from the GVS displayed in the dialogue box. An empty entry appears for the unit in the map window Table of Contents in the geological units folder. Right click on this object and select switch on edit, the entry shows a blue background indicating it is editable (only one unit can be edited at a time)

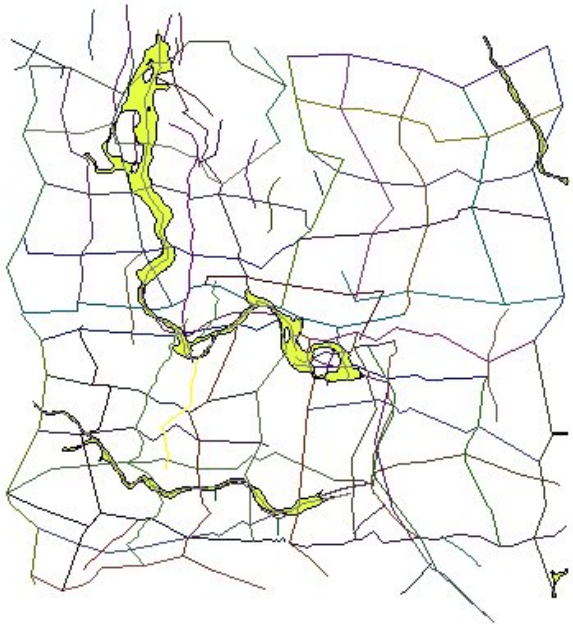
2 Right click again on the required surface (superficial) geology shapefile listed in the map folder object. Sort the table using the relevant field by clicking on the header and highlight all row entries of the alluvium (see Section 3.2.2). Envelopes can also be constructed by selecting only certain polygons from the table checking the selection in the map window. With the desired selection displayed right click again on the map object and select copy. Now right click on the alluvium object in the geological units and select paste. All the selected polygons of alluvium should then display in the map window. If for any reason any polygons are not required at this stage they can deleted manually using the right click on the info icon on the toolbar.

3 The fit of the selected polygons and the cross sections can be checked by right clicking on the envelope (geological unit) name and selecting update. This displays the location of all nodes drawn on the base of the alluvium as crosses along the sections and produces a bedrock line to show the extent of the base along the section.

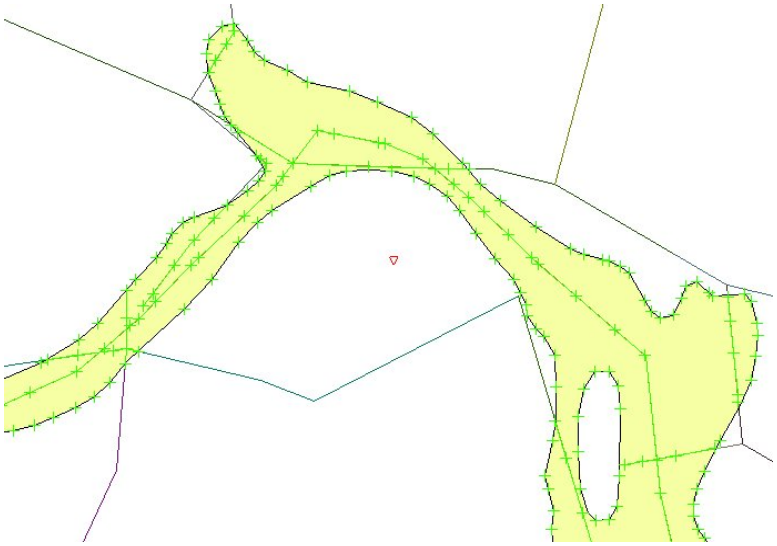
3. Right click again on the unit and select properties to adjust the colour of the crosses and correlation lines so that they are readily visible.

4. Ensure that the bases of the unit correspond precisely with the selected polygons.

5. Right click on the unit and select *switch off edit* then save the *.gsipr



Complete Alluvium envelope for TM14



Detail of the Alluvium envelope showing lines of continuous correlation along sections (solid green lines) and nodes displayed as green crosses along sections and the unit boundaries.

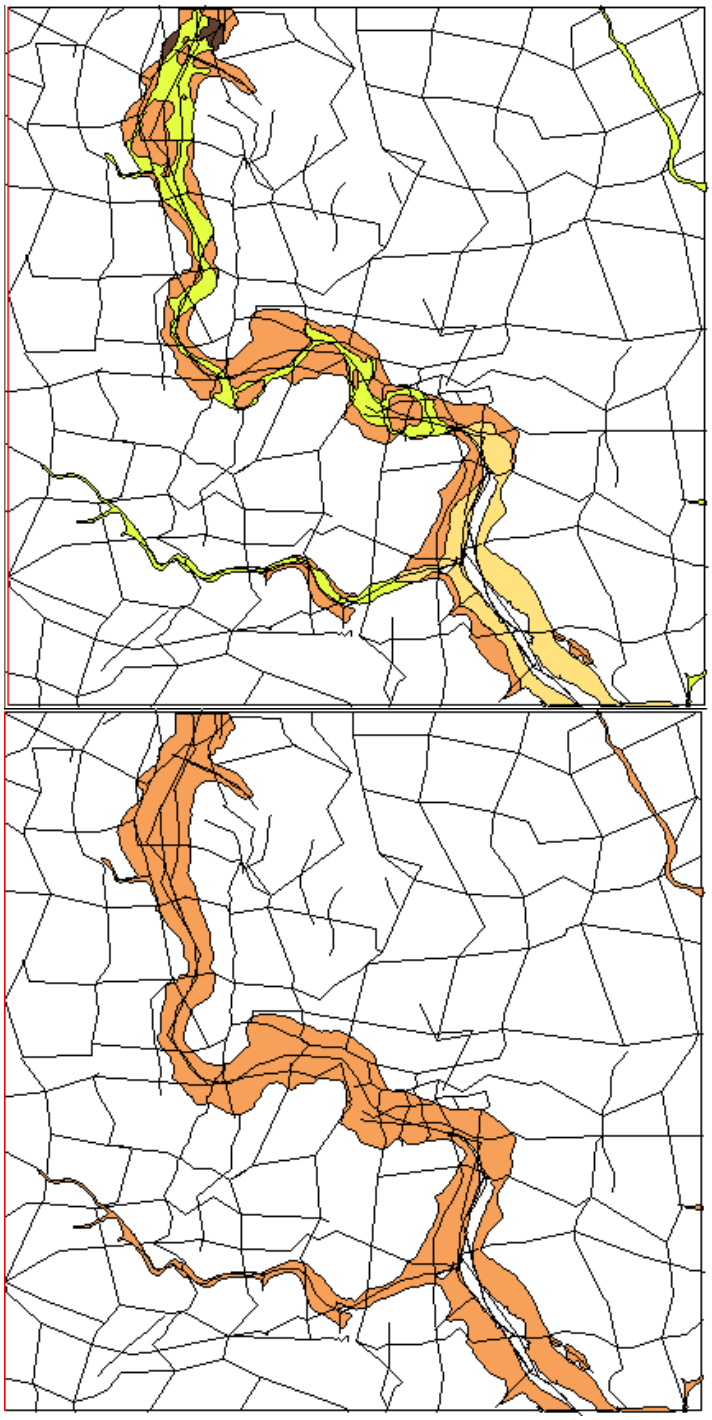
B. River Terrace Deposits Envelope

These deposits occur flanking the Holocene alluvium, peat and intertidal deposits and extend almost everywhere beneath them. We will assume that laterally they pinch out to coincide with the edge of these overlying Holocene deposits where no fringing terrace exists to extend the distribution laterally.. Then:

1. Repeat Stage 1 of the procedure for alluvium above this time setting up the River Terrace Deposits object, make the object editable (right click.> switch on edit).
2. Repeat Stage 2 of the procedure for alluvium this time selecting all the polygons for the River Terrace Deposits and all the overlying Holocene units (alluvium, peat and intertidal deposits). This is because of our assumption that the river terraces extend beneath the Holocene deposits and coincide with their distribution
3. Click on the Combine adjacent polygons and fill holes icon (no 13 on the toolbar see Section 3.2.1) icon and allow time to refresh, the polygons should fuse to make a single envelope corresponding to all alluvial deposits along the valleys including the fringing terraces which in this area all abut the Holocene deposits.
4. Switch off the geology map, right click on the unit layer and update, alter the properties of the crosses and solid lines along the sections to make them readily visible.
5. Examine the correspondence between the envelopes and crosses and correlation lines.
6. Within the area of the selected envelopes there should be no breaks in the correlation line along any of the sections. If there are then at these points river terrace deposits are absent. Show boreholes in the vicinity if any to establish the extent to which the terrace deposits are cut out and then use the polygon drawing tool to draw the area, this then cuts it out from the envelope leaving an island within the polygon.
7. Outside the envelope there should be no crosses on the section lines, if they occur there are two main possibilities. If the correlation line has been poorly drawn in the section it may extend just beyond the mapped limit of the deposit in this case simply identify and display the section in the section window and reposition the final node in the section to fit the geology, confirm the edit by using *update* for the map window. The river terrace may

however actually extend beyond its crop beneath another unit (other then alluvium, intertidal deposits and peat). Here thin superficial deposits such as “head” may overlie river terrace deposits. Magnify any areas concerned and show the geological map and envelope by making the envelope the top layer and partly transparent. Select the edit polygon tool and drag the nodes of the river terrace envelope over into the head polygon to show that the river terrace extends some way beneath it, query any boreholes to assist with repositioning the line.

8. Switch off edit and save the *.gsipr

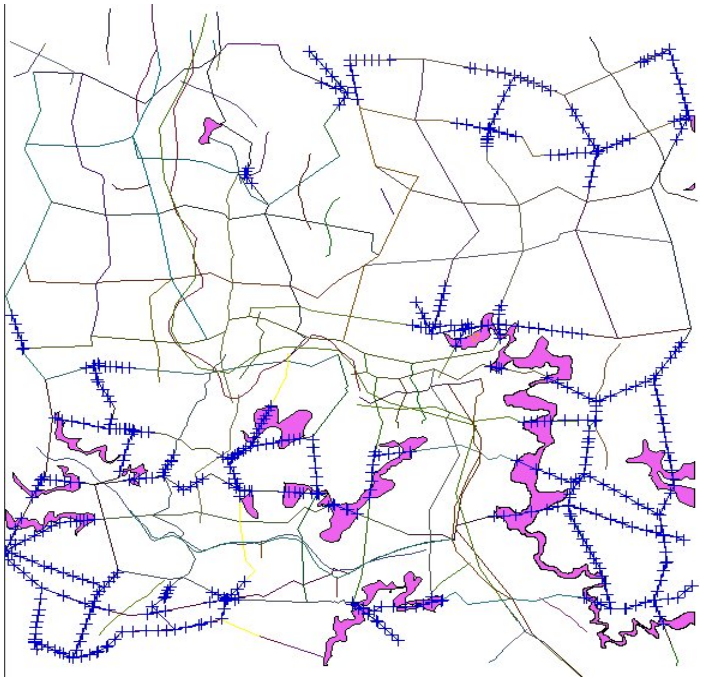


River Terrace Deposits envelope in construction, above all four units selected and below fused.

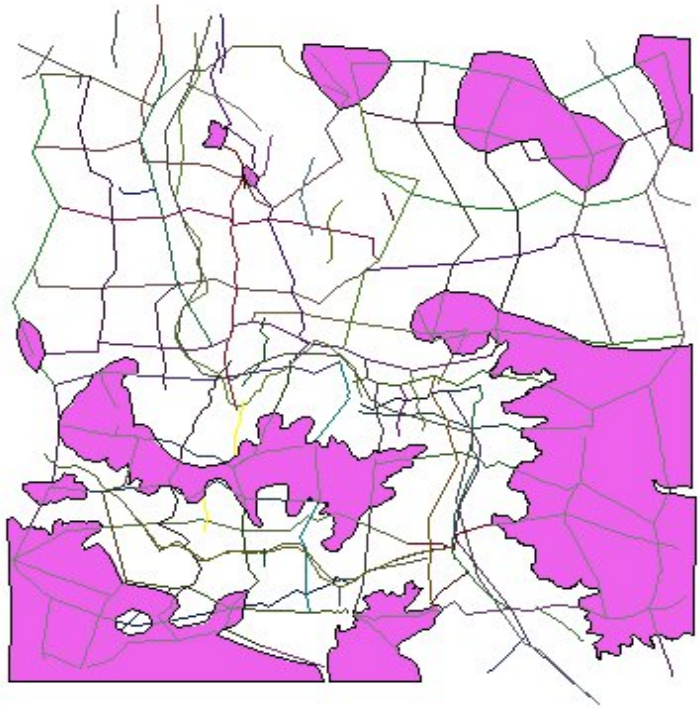
C. Kesgrave Sands and Gravels Envelope

The drawing of the Kesgrave Sands and Gravels envelope is very complicated and is for the advanced or experienced user, there are several ways to approach it. The approach described below selects the surface outcrops and extends them outwards and merges them where needed to produce the envelope. An alternative is to select the surface outcrops and those polygons of units largely overlying the areas where the sections show Kesgrave sand and gravels to be present at depth and combine the two. The job then becomes one of trimming back and editing the envelope of these large combined polygons based on the sections and boreholes. Outlier subcrops and cut out islands within the major polygons would be treated the same way as described above but the cut out islands must not be drawn until the combine polygons button has been used as it deletes them.

1. Repeat Stages 1 and 2 described above for alluvium
2. The key evidence for drawing this envelope is found in the surface outcrop of the unit and the extent of the unit at depth as revealed in the sections displayed in the map window using the update option.. Be aware of the topography and which parts of these polygons are the bases which will be needed as the boundary of the envelope and which parts are the tops, which will be either edited or discarded.
3. Start to extend the surface outcrop polygons by chopping off using the *split polygon* function large chunks encompassed by the top of the unit i.e. areas where younger strata generally overlie the Kesgrave Sands and Gravels. Extend the simplified polygon produced by the cuts outwards to conform to the extent of the unit at depth as shown along the sections.
4. Where two of these expanding polygons meet drag one over the other to create an obvious overlap and then use the *combine polygons* tool to unify them.
5. Compare the emerging pattern with the geological map, and identify any areas where totally buried subcrops are present, insert these into the layer by constructing a polygon based on the crosses and correlation lines along the sections and query any nearby boreholes not on sections to help refine the shape.
6. Identify any islands within the main polygons where the Kesgrave sands and gravels are cut through. Again draw polygons to cut away the deposit by looking at the section crosses and correlation lines along sections and also any nearby boreholes not on sections to help refine the shape.
7. Check that the limits of the polygons are tucked beneath younger deposits wherever the polygon boundary is not an exposed base of the unit otherwise an outcrop not shown on the geological map is implied.
8. Review carefully and when happy with the layer map switch off the edit and save the *.gsipr



Outcrop of the Kesgrave Sands and Gravels and nodes shown as crosses along sections showing extent of subcrops

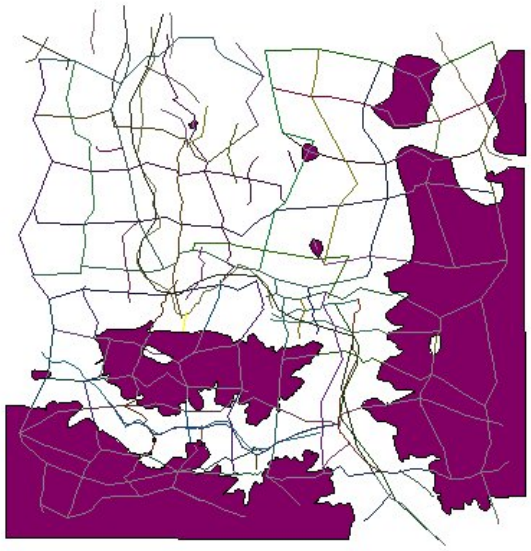


Completed envelope for the Kesgrave Sands and Gravels

D. Red Crag Envelope

The Red Crag envelope is constructed using the bedrock geology map rather than a superficial and bedrock combined (surface geology) version.

1. Repeat again Stages 1 and 2 from the alluvium using the bedrock shapefile to select all the Red Crag polygons.
2. Magnify any areas where the bedrock geology shows the Red Crag to be overlain by a younger bedrock unit (the Chillesford Sand).
3. Update the map window and use the crosses and correlation lines on the sections and boreholes if any to extend the Red Crag polygon beneath the Chillesford Sand.
4. Switch off edit and save *.gsipr

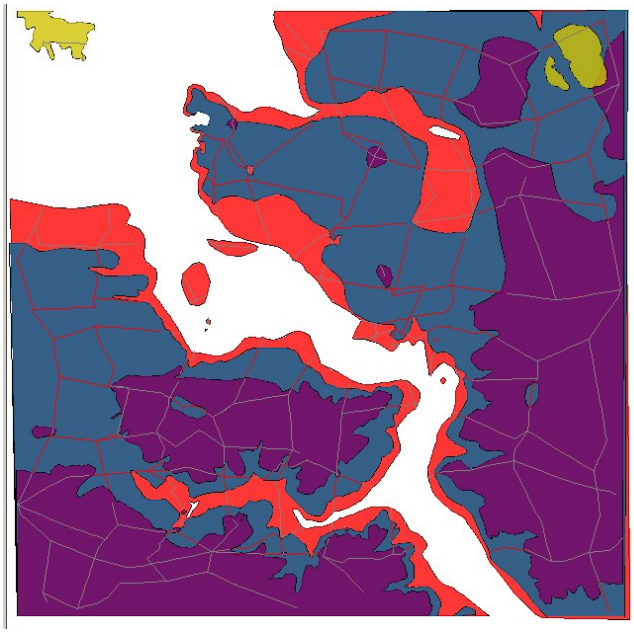


Red Crag envelope

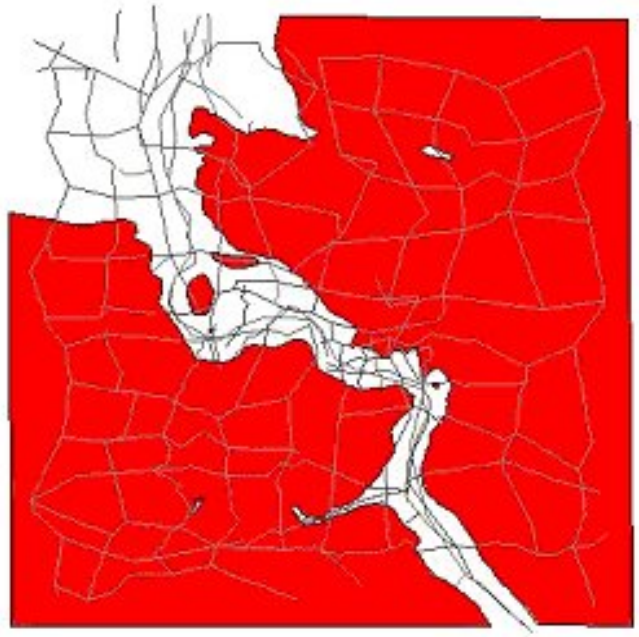
E. Lower London Tertiaries Envelope

The Lower London Tertiaries envelope (Lambeth Group and Thanet Sand Formation undifferentiated) is again relatively straightforward, where it is present it always rests on the Chalk and is not cut through in this area by any younger bedrock units.

1. Repeat Stages 1 and 2 above this time selecting all the bedrock polygons the Lower London Tertiaries, and the overlying Thames Group, Red Crag and Chillesford Sand: Click on the merge adjacent polygons and fill holes icon to fuse the polygons into a single envelope.
2. This yields two large polygons and three small ones the latter are minor outliers beneath the Orwell-Gipping valley.
3. Identify any windows where quarries or superficial deposits have cut through the Lower London Tertiaries to Chalk within the two major polygons, there are 5 in all.
4. Select each of these 5 polygons individually using the *Info* tool and then the *insert polygon* tool to cut out these areas as holes within the layer distribution. **NOTE: this can only be done after merging the encircling polygons.**
5. Switch off edit, save the *.gsipr



Bedrock geology of TM14



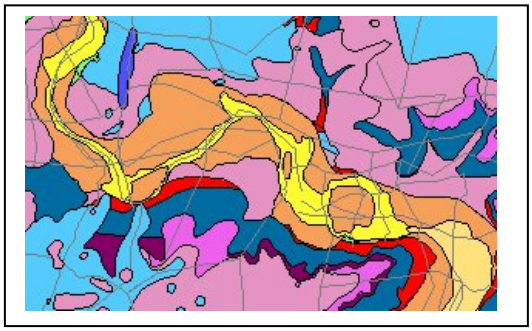
Lower London Tertiaries envelope

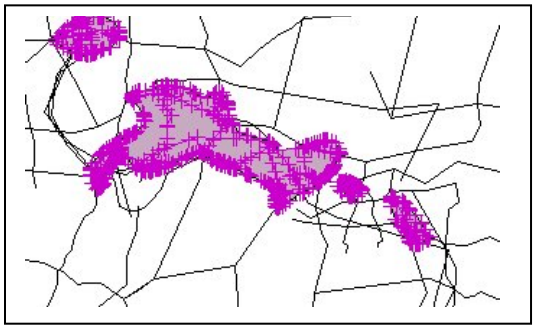
F. Glacial Channel Deposits Envelope

Glacial Channel deposits up to 50m thick occur infilling deeply incised tunnel-valleys in the Ipswich area. Some but not all of these features lie below the floors of the major present day valleys such as the Gipping-Orwell.

The deposits are known only from boreholes and they do not crop out at surface, construction of an envelope for these deposits is thus achieved by displaying the correlation nodes along the sections in the map window. In this case it was useful to draw additional short helper sections in

varied orientations to include all boreholes encountering the deposits in order to define tightly the extent of these buried deposits. The surface geology of central Ipswich is shown below left, the extent of the deposits is indicated as a continuous purple line along the lines of section with each node shown as a cross. Envelope construction is performed using the draw polygon tool to trace around the areas where the deposit is present. Even with closely spaced sections several possible ways of joining up the segments of purple lines-crosses are apparent. In this case the alignment of the present valley and the expected direction of ice-flow were taken into account in drawing the form of the final envelope.





Some 19 units are represented in the stacked model for TM14 of which six have been presented here as examples of varied styles of envelope construction. At its simplest envelopes can be divided into surface outcrop envelopes (young unit not overlain) outcrop plus subcrop envelopes (well illustrated above by the Kesgrave Sand and Gravel) and subcrop envelopes of entirely buried deposits. The presence of a bedrock layer in DIGMAP in addition to the surface geology map also provides polygons that can be selected to help in drawing either outcrop and subcrop or purely subcrop envelopes for bedrock units.

TIP: When drawing envelopes close to the boundary of the project DTM, ensure that the envelopes themselves are stretched beyond the margin of the project area (DTM).

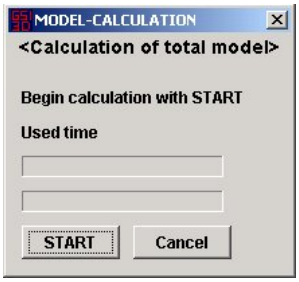
NOTE: When drawing envelopes for discrete lenses, this is only done for the top of the unit the base of the lens will be automatically generated.
Because the elevation of the lense envelope is calculated from the end points of its correlation lines it is particularly important to work towards a perfect fit (< 5 metres) between correlation lines and the envelope boundary. Using the JAVA console it is possible to check if lenses have been calculated properly.

4.8 Calculating the model

Once a DTM (model cap) has been defined and envelopes and sections are drawn the user can calculate all geological units within the model by using the *Calculate triangulated volumes* function under the *Analysis* pull-down menu on the main toolbar see also Section 3.1.1.4.

NOTE: The surface used for calculation is the one defined in the workspace properties box see Section 3.1.1.1, it is therefore possible to calculate a model capped by any loaded surfaces (e.g. DTM, rockhead, watertable etc)

Clicking on the start button shown below the model calculation is set in progress.



NOTE: The calculation is complete once the START button changes to OK.
NOTE: Before calculating the model, the editing of all geological units (the blue edit highlight) must be switched off.

After making iterations the whole model must be re-calculated, as there may be knock-on effects transmitted through the stack. This is a fundamental principal of GSI3D method that ensures the maintenance of a dynamic instead of a static model!

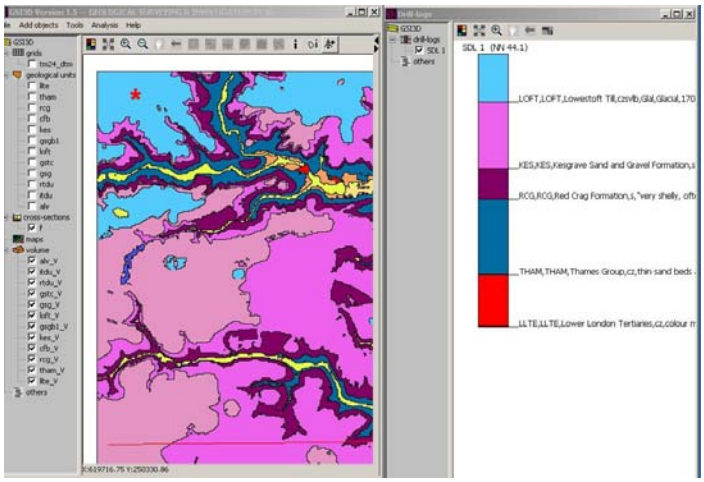
After calculating the geological units the user can then export them as a *.gxml model file under *File - Export-Save model as viewer file (*.gxml) or as a rasterised viewer file* under *‚Export-Save viewer model as raster gridded units* described above in 3.1.1.1.

4.9 Visualising and Analysing the model

The finished model can be exported to the Sub-surface Viewer (see Section 5.1) and its use is described in BGS (2008). This route is taken for model delivery to external clients or internal viewing once a model has been approved and been declared completed.
This section describes how geological models can be viewed and checked within GSI3D in an on-going modelling project involving frequent iteration and cleaning of the model.

4.9.1 Synthetic logs

After calculating the model the geologist can use the synthetic log tool (see Section 3.2.1) to create virtual boreholes anywhere in the area. These can be useful in planning drilling programmes for ground-truthing and model testing. The synthetic logs are displayed in the borehole viewer window and the attribution is retrieved from the GVS.



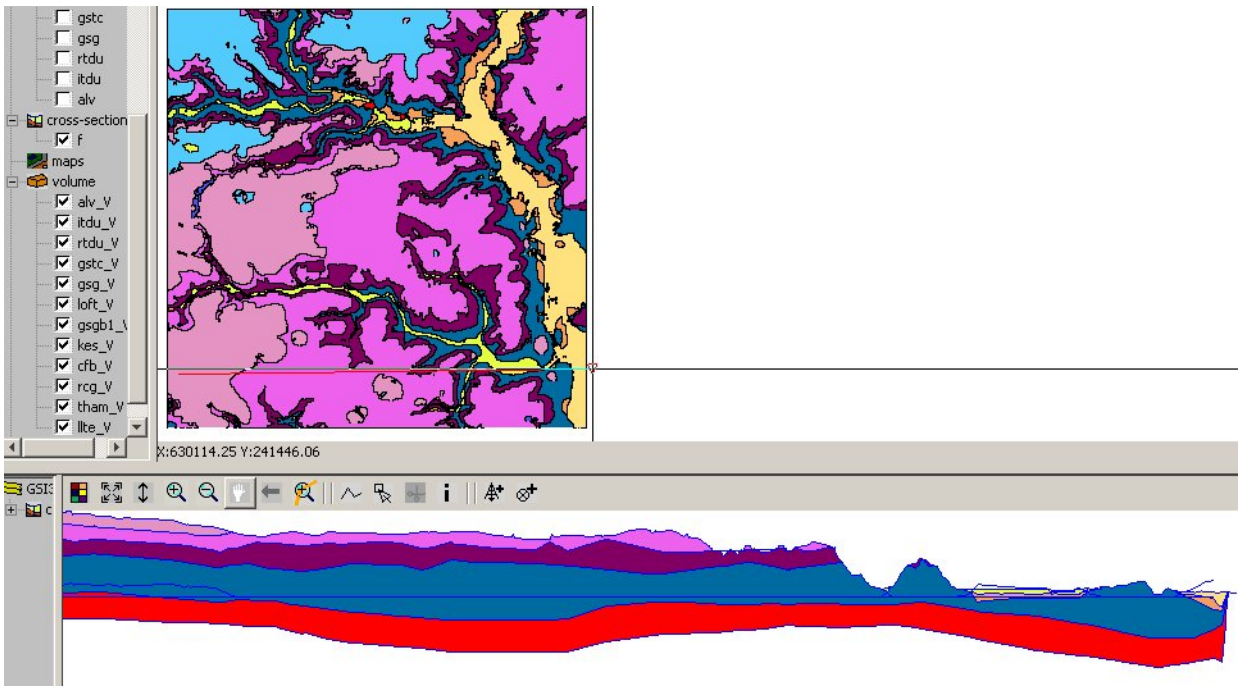
Synthetic log, generated from TM24 model

4.9.2 Synthetic sections

One of the best insights into the integrity of the produced model is to draw synthetic sections through it (see Section 3.1.1.3). This can be along or across geological and geomorphological structures

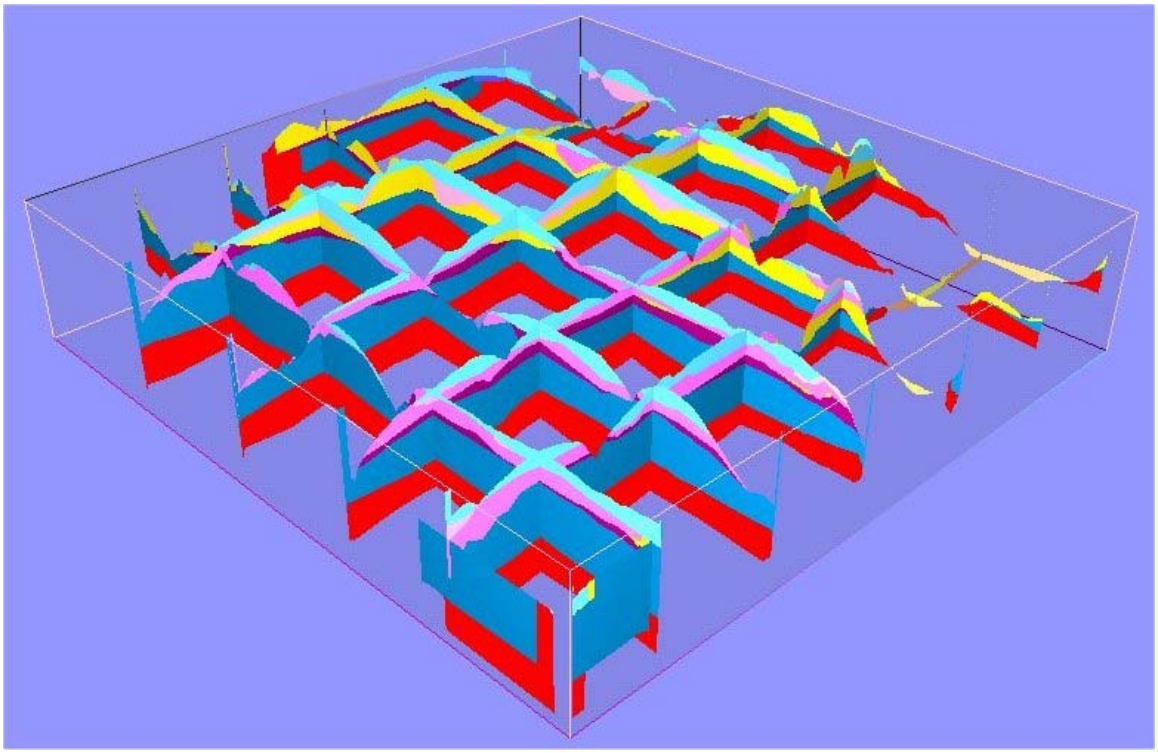
To create synthetic sections:

1. Load project and calculate
2. Go to *Tools: create new section.* Use the info tool to place the cursor on the map and use add point to section in the section window. Repeat this until you have a completed cross-section.
3. Set the properties in the section window (right click) and select the correct GVS column and tick both lines and polygons.
4. Set the appropriate vertical exaggeration.



A particular use of this functionality is to predict ground conditions along pre-determined routes such as flood embankments, tunnels and pipelines, or to help to evaluate the merits of several proposed routes.

Combining multiple sections in the 3D window leads to the creation of fence diagrams such as the one below, here based on a regular spacing.

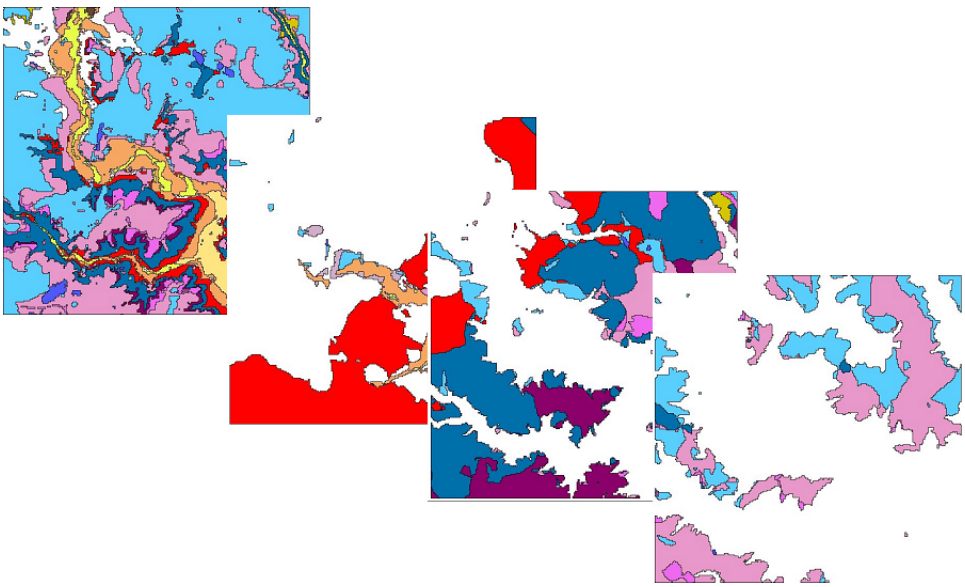


Synthetic fence diagram for TL83, viewed from the south-east,.

NOTE: Any other loaded surfaces (e.g. watertables or Rockhead) will also be displayed in synthetic sections.

4.9.3 Synthetic slices (horizontal sections)

A particularly useful way of testing and presenting your model is to generate horizontal slices at various elevations as illustrated below. The procedure to specify the elevations is outlined in Section 3.2.2.

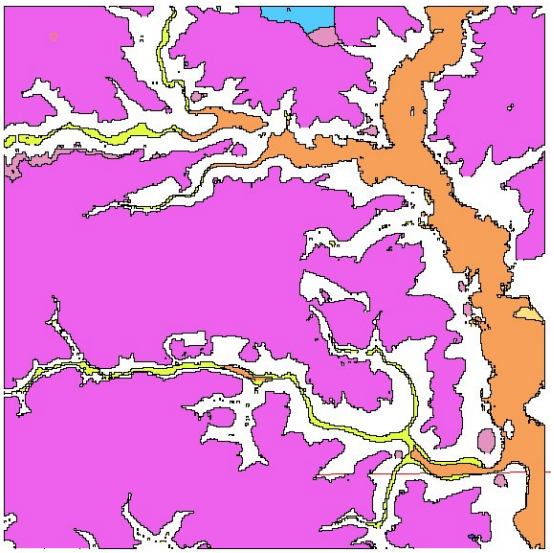


From top left to bottom right, solid model for TM14 and horizontal slices at OD, +20 and +40 metres showing possible faulting in Tertiary deposits.

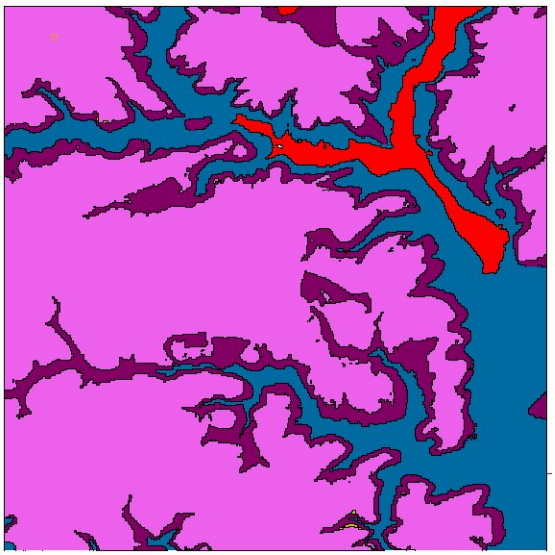
4.9.4 Subcrop and Supercrop maps

These maps show the arrangement of geological strata resting below or above any defined geological horizon most commonly unconformities such as base of Quaternary, top of Chalk and top of Palaeozoic basement. In GSI3D it is possible to instantly produce these plots for any surface (top and base) defined in the GVS. These maps are generated by looking at the sequence in ascending or descending order (see Section 3.2.2) and switching on or off the units you which to be represented in the TOC of the Map Window. If the map units are not in the correct stratigraphic order use the sort gvs function by right clicking on the geological units folder.
Below are two examples taken from the Ipswich area

.



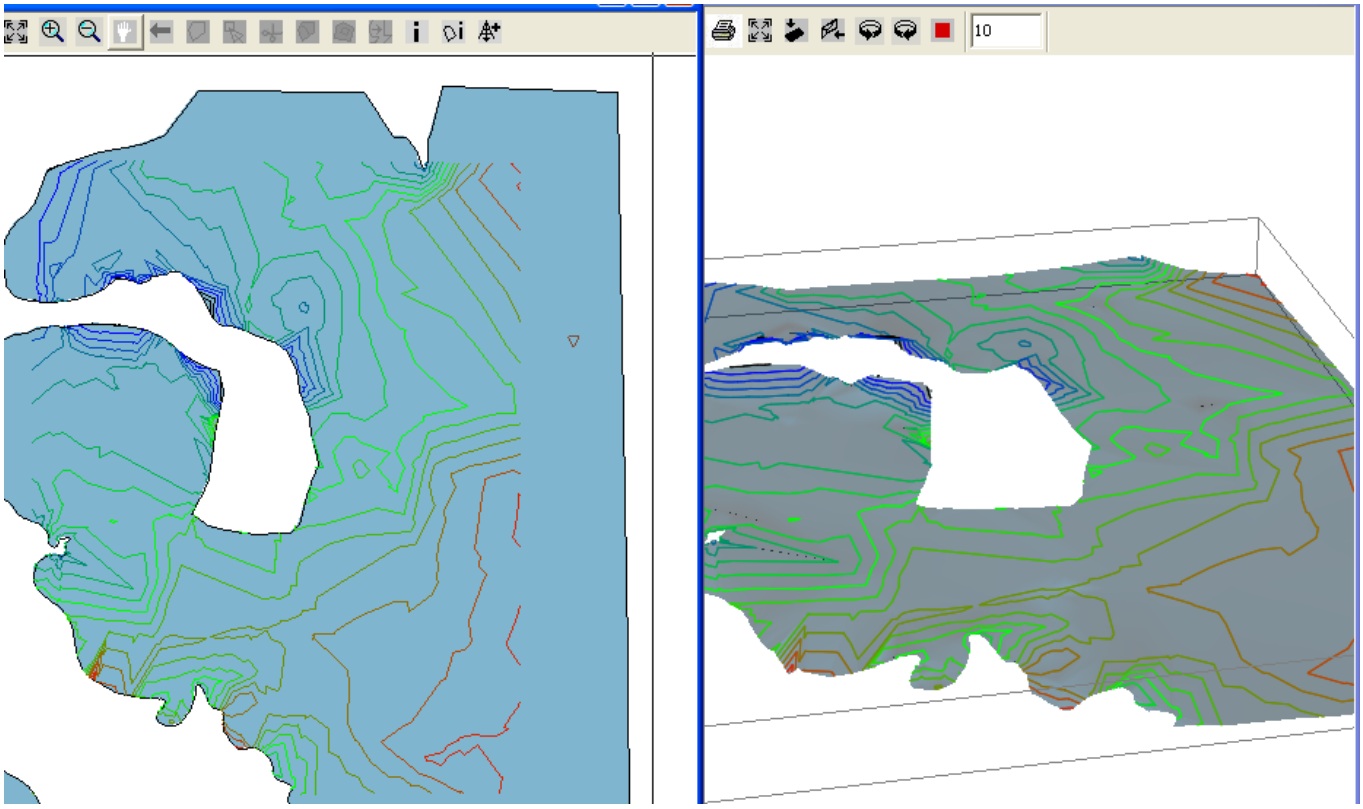
Supercrop map on top of the bedrock for TM24 (areas white show bedrock at outcrop)



Subcrop map on the base of Anglian and younger deposits.

4.9.5 Elevation maps

It is possible to analyse every geological unit by displaying the elevation of its top and base as a shaded relief map or with contour lines at user specified intervals. These can be visualised in the map and 3D window as described in Sections 3.2.2 and 3.4. These contours are controlled via the geological unit property boxes in the map and 3D windows.

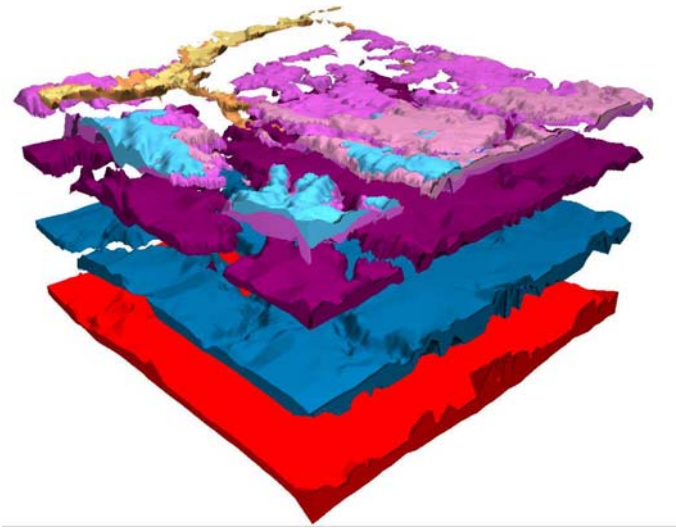


Contours on the base of the Thames group (London Clay) for TM24: Colour ramp red for low elevations to green for high elevations, interval 1m.

Grid exports from GSI3D described in Section 3.1.1.1 can be imported using the Load DEM option from the Add Objects pull down menu (section 3.1.1.2) and visualised in the map and 3D windows as shown above

4.9.6 Exploded views

The most impressive tool of all for displaying the model is the ability to explode the layers in the stack by transposing their z values up or down to achieve separation, this procedure is described above in Section 3.4.2. Using this function to alter the positions of layers and switching them on and off geological time can be recreated by sequentially welding the units back together in their ascending stratigraphical order gradually recreating the block model.



Exploded block model of TM24 down to the Chalk viewed from the northwest.

4.10 Fitting together models

When working in large modelling projects, procedures may be needed to ensure consistency between several small individual models that may be eventually combined into an overall model.

In case of rectangular or tile models "Docking sections" can be constructed **along the grid line** forming the common boundary of the two adjacent sheets. Once drawn this section is copied into both sheet folders in identical form and can be labelled appropriately (e.g. TM14_dock_east and TM24_dock_west). In irregular shaped project areas these sections do not need to be linear.

TM14 Central Docking Section TM24

Docking section between TM14 and TL24 (Ipswich area) i.e. TM14_dock_east and TM24_dock_west.

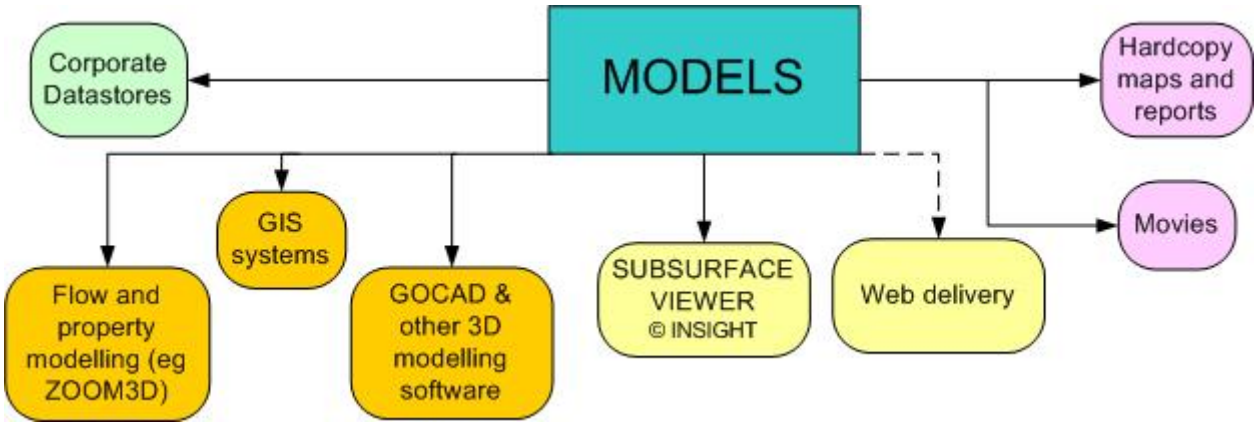
Envelopes must extend beyond the limits of the project area or DTM (see Section 4.7) where they reach to the edge and extend beyond the boundaries of a sheet or a project area.

When loading adjacent projects with overlapping envelopes, these are automatically loaded into

the same project (and can be saved as a new gxml project file) and using the envelope editing tools (described in Section 3.2.1) they can then be merged into continuous envelopes.

5. Linking GSI3D with other applications

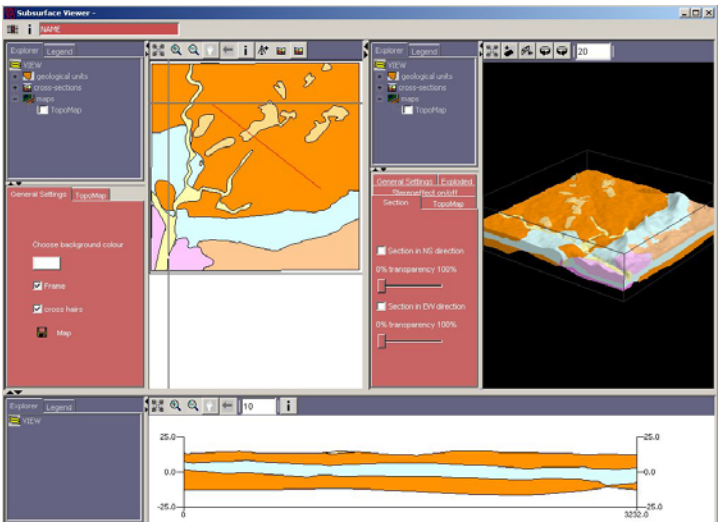
This chapter describes the interaction between GSI3D and other software and the generation of products.
The diagram below shows the most common links and these are illustrated with examples below.



5.1 Sub-surface Viewer

The Sub-surface Viewer is a stand alone product for the delivery of any geoscience models to customers. It as been developed and is licensed by INSIGHT. A separate User Manual for the Sub-surface Viewer is available (BGS 2008)
In order to publish a GSI3D model in the Sub-surface Viewer the user has to complete a model preferably with a GVS file that contains sensible and meaningful entries – see
After calculating the model file (see Section 3.1.1.4) the model is simply saved as a volume model file 3.1.1.1 (triangulated or gridded). This file can then be directly incorporated into the Sub-surface Viewer.

NOTE: Any models that can be loaded into GSI3D can be published in the Subsurface Viewer



The Sub-surface Viewer © INSIGHT, showing the York model (Price 2004)

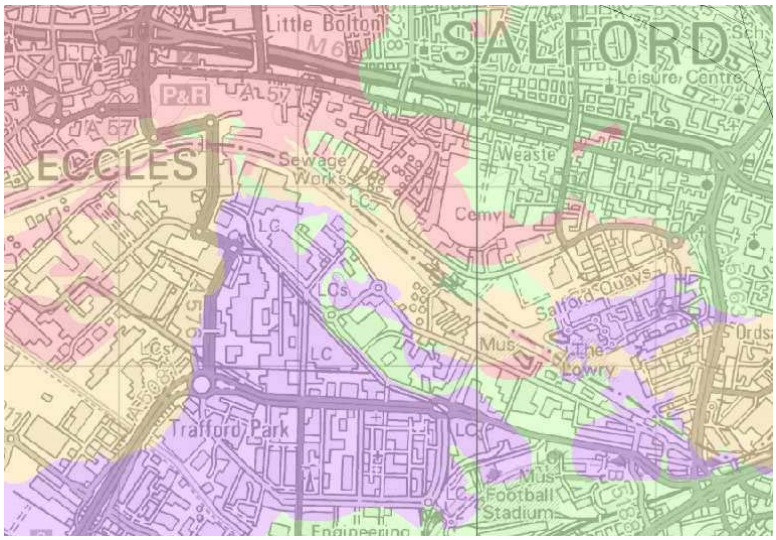
5.2 GIS

The most common interaction of GSI3D outputs is with GIS systems. The following table lists the possible exports and their file formats.

Output	Data type and format
Envelopes	ESRI shape file
Horizontal slices	ESRI shape file or geo-registered JPEG image
Sub and Supercrop maps	ESRI shape file or geo-registered JPEG image
Grids of the base, top or thickness of geological units. Combined units.	ASCII grids

GSI3D can exports all geological units (envelopes, base, top and thickness) as standard ESRI shapes and ASCII grids after model calculation (see Section 3.1.1.4). Any map view in GSI3D can be directly exported as a geo-registered tiff image for quick visualisation in GIS by clicking the save map window as image icon in the map window toolbar.

The use of these exports in GIS software is manifold and new ideas are being developed all the time. Below one example is shown where a full GSI3D model has been analysed to create a hydrogeological domains map.



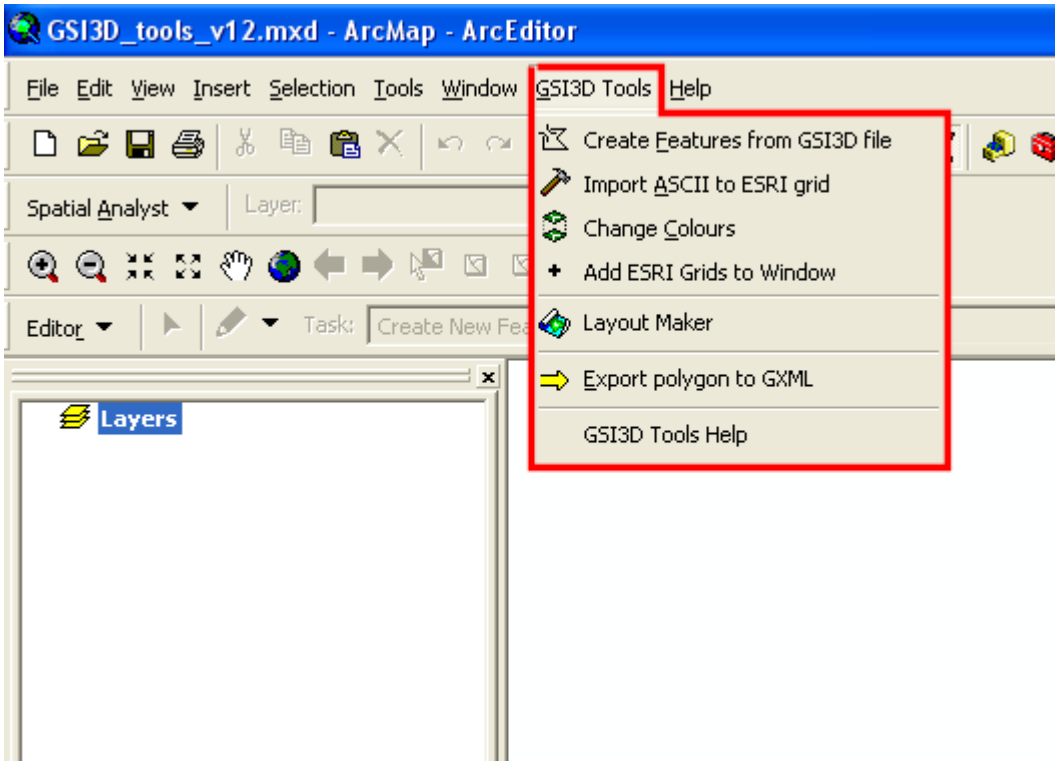
Extract from the Manchester Hydrogeological domains map derived from a GSI3D model (Kessler et al. 2004a). Red areas are thin or no deposits over aquifer, blues are perched aquifers, yellow are thin clayey units at surface and green are thick clay rich deposits.

In addition to these standard GIS functions BGS has developed the Arc toolbox explained below:

The GSI3D_tools.mxd is an ArcMap 9.x project, built in 9.2, but should therefore work with ArcMap 9.0 and 9.1. TheGSI3D tools reside under the GSI3D Tools in the GSI3d_tools.mxd

There are 7 individual tools:

1. Create Features from GSI3D file
2. Import ASCII to ESRI grid
3. Change Colours
4. Add ESRI Grids to Window
5. Layout Maker
6. Export polygon to GXML
7. GSI3D Tools Help



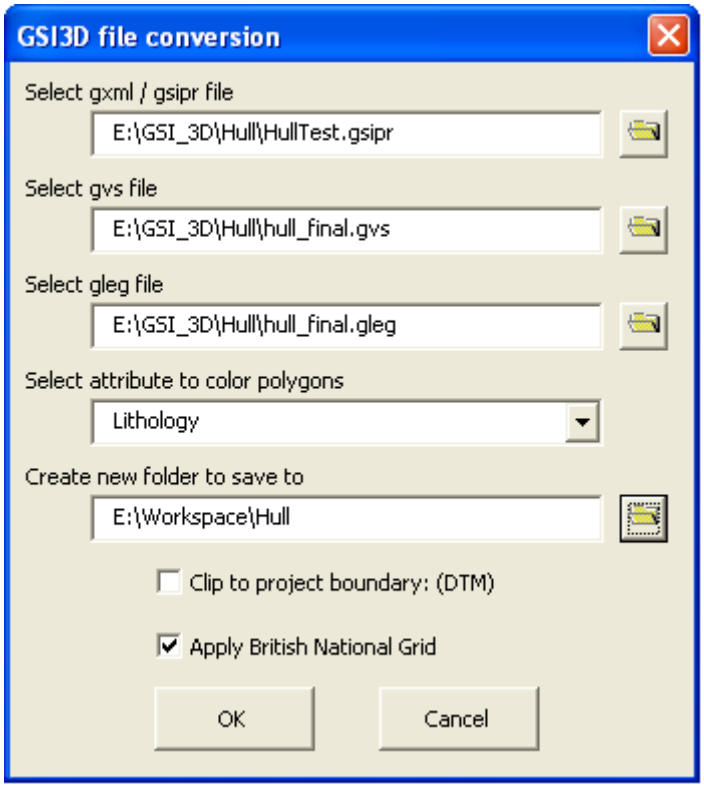
1. Create Features from GSI3D file

This tool extracts the boreholes, section lines and envelopes from either a *.gxml or *.gsipr file, converts them to shapefiles, and adds them to the map window. If a *.gvs and *.gleg file is specified then the program will order the layers in stratigraphical order, and colour according to the legend.

Instructions:

1. Select the 'Create Features from GSI3D file' function.
2. Browse to the location of your *.gxml or gsi3d file.
3. Browse to the location of your *.gvs and *.gleg file. NB Where possible, the code will automatically extract these from the header information of the *.gsipr file.
4. Select an attribute to colour the shapefiles. This box is automatically populated with attributes from the *.gvs.
5. Browse to the location where you wish to save the data, and type in the name of a new folder.
6. Select whether to clip the data to the project boundary. The project boundary is extracted from the *.gsipr file, so is unavailable if you are converting a *.gxml file.
7. Select whether to use the British National Grid projection.
8. OK

The time it takes to process the data depends on the complexity of the GSI3D file. The application message bar highlights the status of the program.



2. Import ASCII to ESRI grid

This tool imports ASCII grids to ESRI format. If there are any thickness grids missing, this tool will create these in both ESRI and ASCII grid format

Instructions:

1. Select the 'Import ASCII to ESRI grid' function.
2. Browse to the location of the ASCII files.
3. Browse to the location where the ESRI grids are to be saved.
4. The program will then ask whether the grids are floating point grids (i.e. whether the grid values contain decimal places).
   <u>Note:</u> Floating point ESRI grids take up significantly more memory than integer grids. If the data is held as in integer grid, it is advisable that this format is maintained. If you have a floating point grid and 'no' is entered to the above message, the grid will still be created, but with integer values.

The application bar in the bottom left hand corner of ArcMap reports on the status of the program.

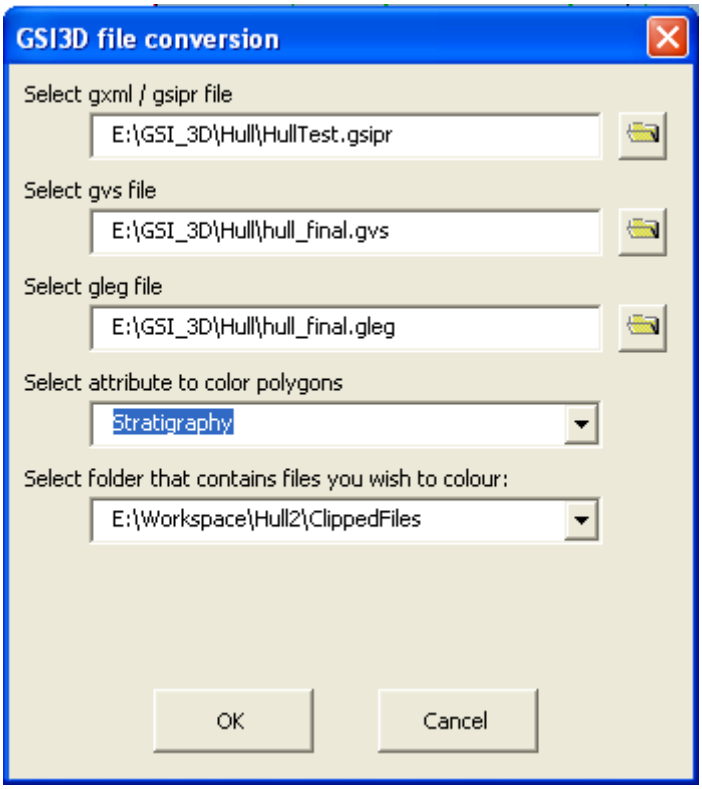
3. Change Colours

This tool changes the colours of the layers already in the map according to an attribution in the *.gleg file. The colours of both polygons and grids can be changed in this way.

Instructions:

1. The layers you wish to colour must already be added to the map
2. Select the 'Change Colours' function.
3. Browse to the location of the *.gvs and *.gleg file.
4. Select an attribute to colour the shapefiles. This box is automatically populated with attributes from the *.gvs.
5. Select which folder contains the data you wish to re-colour. This will be automatically populated with the data sources of the map layers.
6. OK

Please note that only a new group layer will be created which contains only the colours and not the shapefiles themselves. ArcView *.avl files will also be created for each shapefile.



4. Add ESRI Grids to Window

This tool adds ESRI grids to the map window, and colours them in accordance with the *.gleg, and orders them stratigraphically as listed in the *.gvs. The grids must be in ESRI format. If a thickness grid does not exist, this function will automatically create one.

Instructions:

1. Select the 'Add ESRI Grids to Window' function.
2. Browse to the location of the folder containing your ESRI grids.
3. Browse to the location of the *.gvs and *.gleg file.
4. Select an attribute to colour the shapefiles. This box is automatically populated with attributes from the *.gvs.
5. OK

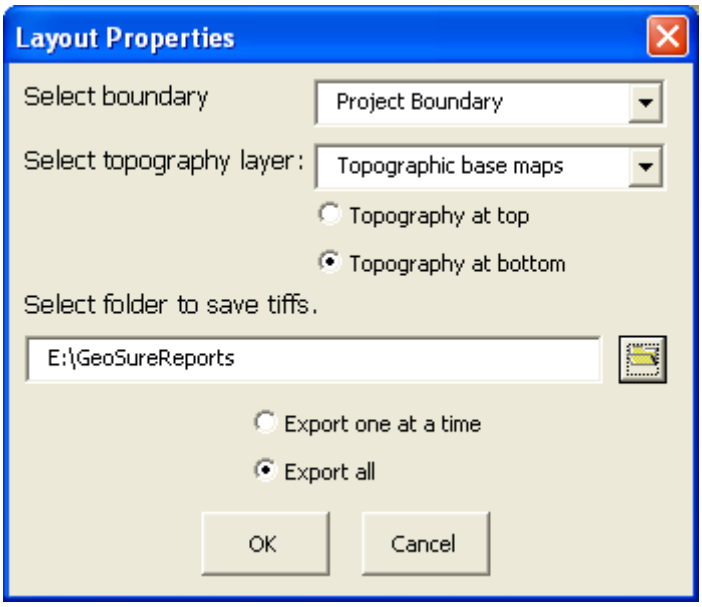
5. Layout Maker

This tool creates a layout view, automatically adds data to it and exports this as a tiff image. There are two aspects to this tool: a complete export facility where everything is exported in one action, and an interactive facility that allows the user to modify certain parts of the layout (titles, legends etc) before each export.

Instructions:

1. Ensure your data, including any topographic maps and project boundaries, are added to the map.
2. Select the 'Layout Maker' function.
3. Select your boundary layer and topographic layer, or keep blank if not present.
4. Select whether you require the topography to be at the top (if it is translucent) or at the bottom.
5. Browse to the location where you would like the tiffs to be saved to.

6. Select whether to export the tiffs one at a time (see below), or all in one action..
7. OK

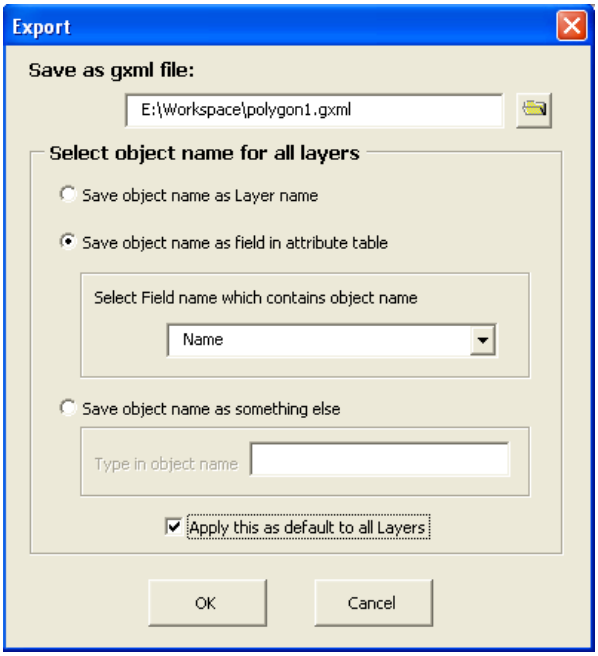


If you select to export the tiffs one at a time, then another window will open that will allow you to go through each layer, modifying the layout and exporting the tiff as required.

6. Export polygon to GXML

This tool exports selected polygon(s) to GXML format.

1. Ensure that one or more polygons from one or more layers currently open in ArcMap are selected.
2. Browse to the location where you would like the new *.gxml file to be saved.
3. Select an object name for each object. The object name can be the layer name, an attribute from the layer's table, or something specified by the user.
4. The user will need to set the object name like this for each feature selected. However, the user can set the format of the object name to be the same for all of the selected features by checking the final box.

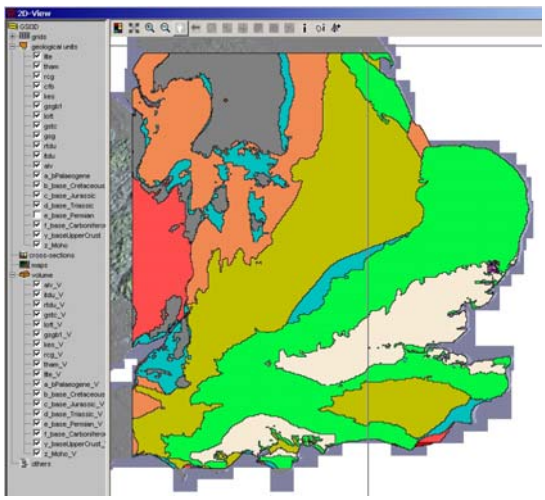

Export
Save as gxml file:
E:\Workspace\polygon1.gxml
Select object name for all layers
Save object name as Layer name
Save object name as field in attribute table
Select Field name which contains object name
Name
Save object name as something else
Type in object name
Apply this as default to all Layers
OK
Cancel

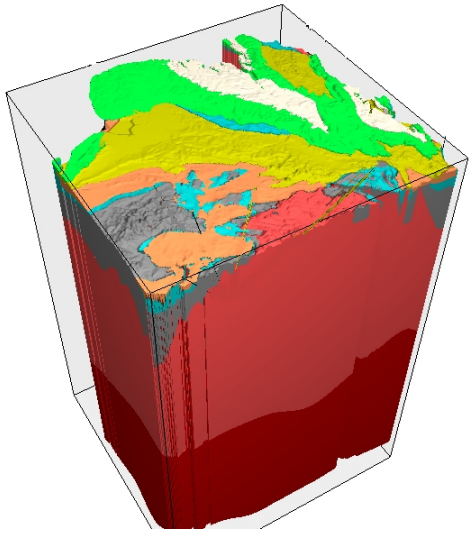
7. GSI3D Tools Help
This opens a window with some troubleshooting tips and suggestions

5.3 Geoscience modelling software

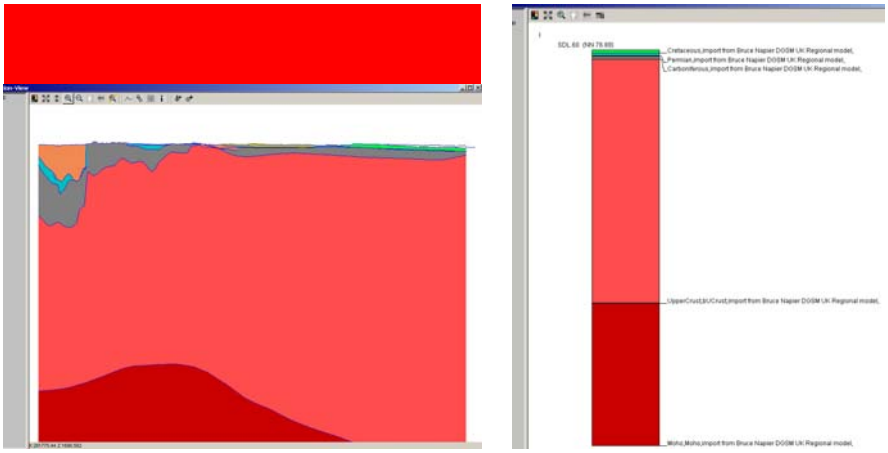
Using the point, grid and TIN export functions described in section 3.1.1.1 GSI3D can export surfaces or volumes to most leading geoscience modelling packages. Exports to Surfer, Rockware, Earthvision and GoCad have been carried out successful.
GoCad is BGS's second approved modelling package for geological modelling and uses the same TIN structure as GSI3D, described in section 2.1.10.

Below are some examples illustrating the seamless interoperability between detailed and regional models from GSI3D and GoCad using the UK Regional Model (LithoFrame 1M) (Napier 2004)



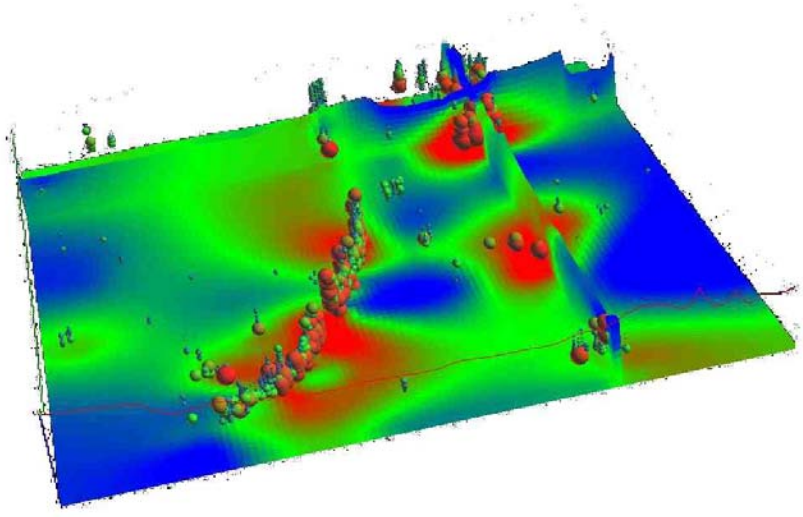


The GoCad model imported and gridded in GSI3D.



A synthetic GSI3D section from Cheshire to Kent through and a synthetic borehole in East Anglia (vertical scale 1:1).

Using GSI3D exports a full volume block model has been built in GoCad as part of the Thames Gateway project. The voxel model was then attributed with SPT test values from engineering logs.



Engineering point data visualised in GoCad for part of the Thames Gateway

6. Technical appendices

6.1 System requirements

- The recommended specification for a PC to run GSI3D efficiently would be based on Intel Pentium 4 2.5 Ghz processor (or better), or an AMD Althon XP 2600 processer (or better). A minimum of 512 Mb system RAM. Windows 2000 service pack 4 or later. XP is preferred. GSI3D will run on MS Vista but is currently unsupported by BGS or Insight.
- A higher-end desktop graphics card preferably NVIDIA Geforce (6600 or better), Nvidia Quadro (FX series or better), AMD/ATI Radeon (9500 or better) based is desirable.
- The GSI3D installation requires at least 120 Mb of free disk space.

Note: The above specification does not cover mobile devices. Varying hardware set-ups on Laptops (in particular the graphic cards) may mean that GSI3D does not perform satisfactory.

It is recommended to have a double screen (or a separate laptop) during the modelling exercise when the user is using the GEOENTRY system (ACCESS front end to BoGe and SOBI), the borehole scans, other GIS system and GSI3D often at the same time.

6.2 Acronyms and GSI3D terminology

ASCII	American Standard Code for Information Interchange
Base	The lower boundary of a particular geological unit GSI3D deals exclusively with the base of geological units
BGprop	Corporate ORACLE table containing geological properties associated via a link ID with BoGe borehole units
BINDEX	ORACLE legacy table containing the 'header information' to BGS borehole records. Precursor to SOBI
BLITH	ORACLE legacy table containing standard stratigraphical and lithological and property data for geological units. Precursor to BoGe and BGprop
BoGe	Corporate ORACLE table containing standard stratigraphical and lithological data for geological units
CEH-DTM	A loosely used term to refer to the nationally available DTM based on OS (Ordnance Survey) 10 metre contour data that has been hydrologically corrected by the Centre of Ecology and Hydrology in Wallingford using additional height information of rivers, streams and watersheds. Currently the only nationwide available, seamless DTM
DEM	Digital Elevation Model. Collective term for DTMs and DSMs

DGSM	Digital Geoscientific Spatial Model. Major BGS programme to standardise BGS data formats and working practices. LINK
DGSM portal	Web based retrieval tool giving access to 'prime' BGS corporate datasets such as DTMs, raster maps, DiGMapGB data, Borehole information, geochemical and geophysical data
DiGMapGB	The digital geological map of Great Britain a database in 4 layers (mass movement, artificial deposits, superficial deposits, bedrock) and 3 standard scales (250K, 50K and 10K). Served on the S: drive and available as ARC and MapInfo polygons
Domain	A 2-D area of similar setting or equal processes. In BGS usually derived to satisfy a particular customer need by interpreting a number of data sources. (e.g. Groundwater Vulnerability zones, Ground stability maps, etc)
DTM	Digital Terrain Model – Model of surface of the solid Earth (generally the boundary between geosphere and atmosphere or hydrosphere). This is traditionally derived from OS contours and spot heights and should therefore exclude all buildings, trees, hedges, crops, animals etc. Sometimes also referred to as 'bald earth' models
Drift	Obsolete term for superficial/ quaternary deposits
DSM	Digital Surface Models are elevation models that include height information from surface objects, such as trees and buildings, as well as from the terrain itself. Examples include unfiltered LIDAR, NEXTMap and photogrammetry produced elevation models
Envelope	Defined here as the extent of a geological deposit in plan view (2D): forming a distribution map of the particular unit, a presence – absence map.
GBASE	Geochemical Baseline Survey of the Environment. Grid sampling of sediments from 0.1 and 0.4 m depth on 2km grid in rural and 0.5 km in urban areas. Described with texture, colour, contamination etc and analysed for ca. 50 elements (an-organics only)
GEOENTRY	Microsoft ACCESS based front end to SOBI, BoGe and Bgprop developed by Ken Lawrie, BGS Edinburgh
GEOHAZARD	Major BGS programme to produce national geohazard datasets for Great Britain. Major deliverables are Scanned Borehole Images, 'Drift' thickness and Rockhead data, Landslide and Karst Hazard layers
GeoSciML	Geoscience Mark-up Language
GSI3D	Geological Surveying and Investigation in 3-D

GLOS	**G**eoscience **L**arge **O**bject **S**tore – The DGSM Oracle store for geoscience models in their proprietary format. GSI3D stores projects IN 'XML' format
GML	Geoscience Mark-up language
GoCad	Geoscience modelling package developed by a French-led consortium
Grid	A rectangular grid attributed with elevation or thickness values of a particular geological unit. GSI3D exports grids as 'ASCII grids' (*.asc) or SURFER grids (*.grd)
GSD	Geological Spatial Database. ArcView 2-D geological data capture tool. Originally aimed at the delivery of a high quality cartographic 1:10.000 map product, later re-designed to capture topologically correct geo-science data.
GSD2	The GSD translated to ArcMap (Under development 08/03)
GSF	Geoscience Spatial Framework - The DGSM Oracle store for geoscientific surfaces in x;y;z plus attributes format. Originally designed for surfaces only but also capable of storing sections (as lines along a surface)
GSI3D TIN	Proprietary TIN export from GSI3D in VRML format 1997
GSIPR	Workspace project file type generated by GSI3D
GXML	The GSI3D mark-up schema and file extension for legacy project and TIN files and viewer model exports.
IMAU	Industrial Minerals Assessment Unit. Major BGS project in the 1970s and 80s carried out on behalf of the Department of the Environment resulting in reports, maps and boreholes describing mainly sand and gravel resources in the UK. Downhole log data is available on BoGe, map data is available as digital polygons and grading data is available on a CD as an ACCESS database.
Lexicon	Short for Lexicon of Named Rock Units. Mega ORACLE table containing the codes, names, definitions and parent/child relationships of all mapped or recorded stratigraphical units in the UK.
LIDAR	Light Detection and Ranging. Laser measured high accuracy (<50cm), high spatial resolution (1/2m) DSM acquired from airborne platform.
LOCUS	London Computerised Underground and Surface Geology .Major BGS project at the beginning of the 1990s generating 4 major geological surfaces for the London area within the M25.
Map	A map is the polygonal representation of geological units or domains projected to a plane perpendicular to the earth's surface.

Model File	A *.gxml file generated in GSI3D containing a calculated geological model
NEXTMap	Suite of elevation datasets and imagery products produced using airborne IFSAR (Interferometric Synthetic Aperture Radar). 5 metre cell size DSM and DEM (filtered) with 1 metre vertical accuracy. Also 1.25 ORI (Orthorectified Radar Imagery) product. Available for the whole of the England and Wales and southern Scotland with plans for complete UK coverage.
Objects	Geological units in a model stack comprising top, base and walls (a.k.a Volumes).
Outcrop	The area where a geological unit is intersected by the earth's surface (DTM).
QMT	Quaternary Methodologies and Training. Major BGS project to describe and standardise working methods and practices for data gathering in quaternary terrain.
Project File	A *.gsipr file generated in GSI3D containing constructed sections and envelopes prior to model calculation
RCS	Rock Classification Scheme (in 4 volumes) describing and defining all 'Rock types' occurring in BGS datasets . These have been codified into an ORACLE table and are published on the www.
Rockhead	Loose term referring to the surface at the top of the bedrock (solid geology) where Superficial Deposits (drift) are present it corresponds to their base.
Section	Defined here as a vertical x, z plane
Shells	The outer bounding surface or skin of a 3D object or volume
SIGMA	Systems for Integrated Geospatial Mapping. Major BGS programme to create and standardise a fully digital workflow for the capture and Storage of geoscience data, mainly aimed at Integrated Geoscience Survey projects
Slice	Defined here for a horizontal x, y plane
SOBI	Single Onshore Borehole Index. BGS corporate database containing the 'header information' to all BGS borehole records.
Solid	Obsolete term for the bedrock or rock units corresponds broadly to pre-Quaternary units.

Start Height	Term used in SOBI for the level at the top of a borehole, usually equates with the height of the surface (DTM) but not always. Equivalent to the collar height.
Subcrop	The distribution of a buried/concealed geological unit beneath younger deposits.
Sub-surface Viewer	An independent software produced by INSIGHT GmbH used to package finished models for sale to customers. The viewer enables basic slicing and dicing analysis of the model which is encrypted within the software. The model cannot be altered or import additional data, the software is not available in a stand-alone form at present.
Supercrop	The distribution of a buried/concealed geological unit above older deposits.
Superficial Deposits	Term used to describe the Quaternary, generally unconsolidated, geological deposits. This has traditionally been called drift
Surface	Base of geological unit exported as grid or TIN
TIN	Triangular Irregular Network. GSI3D exports TINs in Indexed Triangle Mesh format (VRML97)
Unit	A geological unit is a particular geological deposit that has been identified and mapped out during a GSI3D project. A unit is defined by a surface on its base and an envelope of its lateral extent.
Volumes	Geological units in a calculated model stack comprising top, base and walls (a.k.a Objects).
XML	Extended Mark-up language.
XMML	Extended Mining and Exploration Mark-up language

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